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COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT

TUCSON, ARIZONA

RESEARCH REPORT

U.S FISH AND WILDLIFE SERVICE

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ARIZONA GAME AND FISH DEPARTMENT

DISTRIBUTION AND ABUNDANCE OF FISHES IN SHINUMO CREEK IN THE GRAND CANYON

by

Nathan Layne Allan

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In the Graduate College

THE UNIVERSITY OF ARIZONA

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ABSTRACT

Bluehead sucker (*Catostomus discobolus*) and speckled dace (*Rhinichthys osculus*) were the only native species in Shinumo Creek above a waterfall located about 120 m upstream from the confluence of Shinumo Creek and the Colorado River. Rainbow trout (*Oncorhynchus mykiss*) was the only introduced species found upstream of the waterfall. I attribute the coexistence of the native and introduced species is attributed to differential use in resources and the similarly small size of bluehead sucker and rainbow trout. Mean total length of bluehead suckers was 160 mm and the largest fish captured was 230 mm (n=77). Mean length of rainbow trout was 149 mm (maximum=300 mm; n=46). Bluehead suckers in Shinumo Creek were smaller than individuals observed in the mainstem Colorado River. Small size may be a response to the decreased size of the habitat available. The permanence of the waterfall barrier near the mouth of Shinumo Creek is a result of regulation of the Colorado River that prevents inundation of the waterfall.

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INTRODUCTION

The Colorado River drainage extends into portions of seven states and Mexico (Figure 1) and provides water resources for a variety of user groups. Control of the river has been a leading factor in the development of the southwestern United States (Fradkin 1981) but has severely altered the Colorado River ecosystem (Dolan et al. 1974). Before recent modifications in releases (results of efforts to minimize negative impacts on downstream environments), Glen Canyon Dam (construced in 1963) was managed solely to provide peak electrical power generation. This resulted in daily fluctuations in discharge and nearly eliminated seasonal variations (Figure 2). With the exception of 1983 when discharge peaked near 90,000 cubic feet per second (cfs), historic flood events, common before 1963, have been replaced with more consistent releases throughout the year (Carothers and Brown 1991) (Figure 3).

Alterations to the ecosystem of the Colorado River have resulted in the loss of some species of native fish and declines in remaining populations within the Grand Canyon (Carothers and Johnson 1981; Ono et al. 1983; Minckley 1991). Altered water temperatures and exotic species have been suggested as the primary causative agents for these declines. Water temperatures in the river have become much lower than historic values due to hypolimnetic releases from Lake Powell. Laboratory data suggest that spring and summer temperatures may be so low that successful survival of larvae of some native fish species are precluded (Suttkus and Clemmer 1976; Hamman 1982; Marsh 1985). More than 24 exotic fish species now

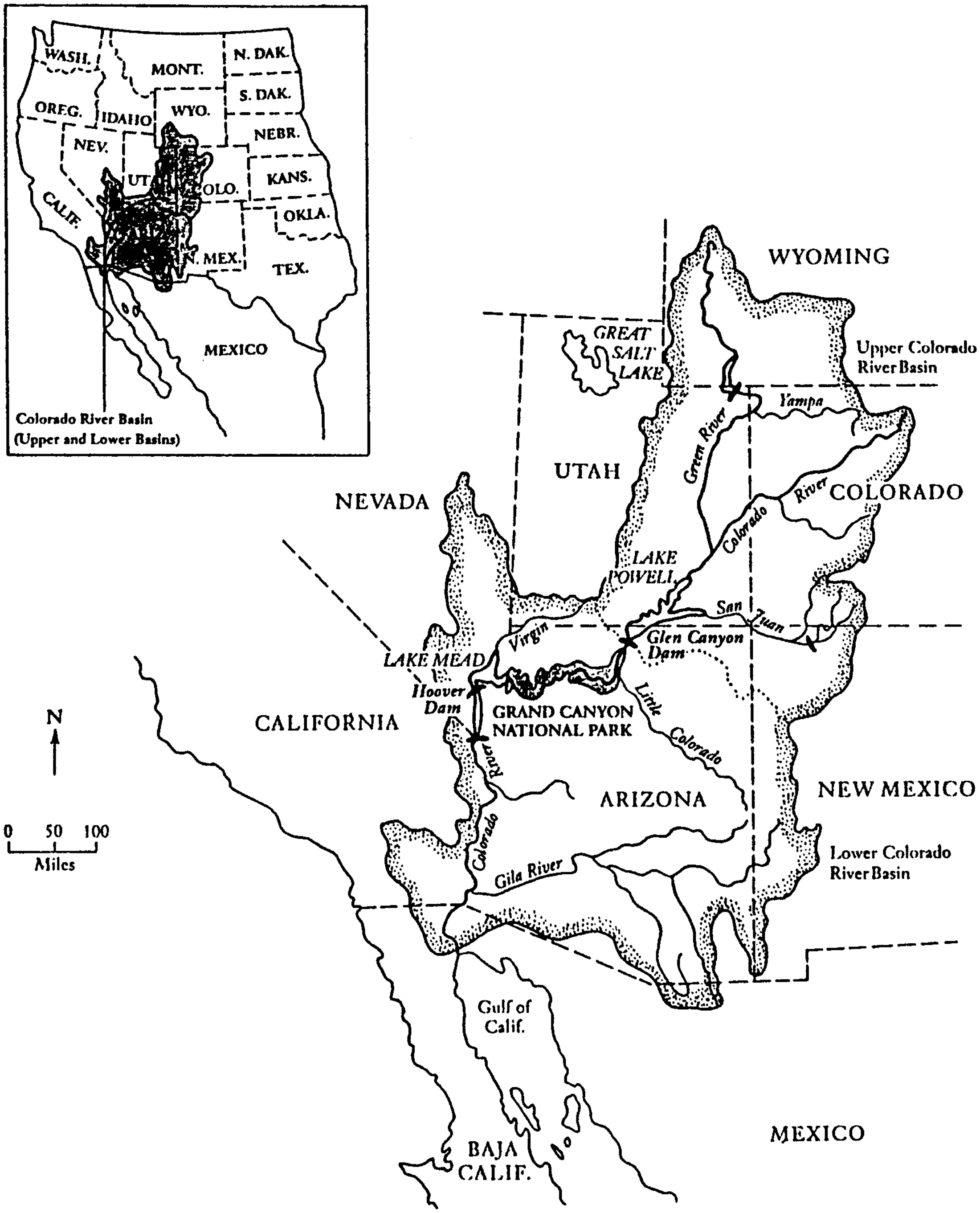
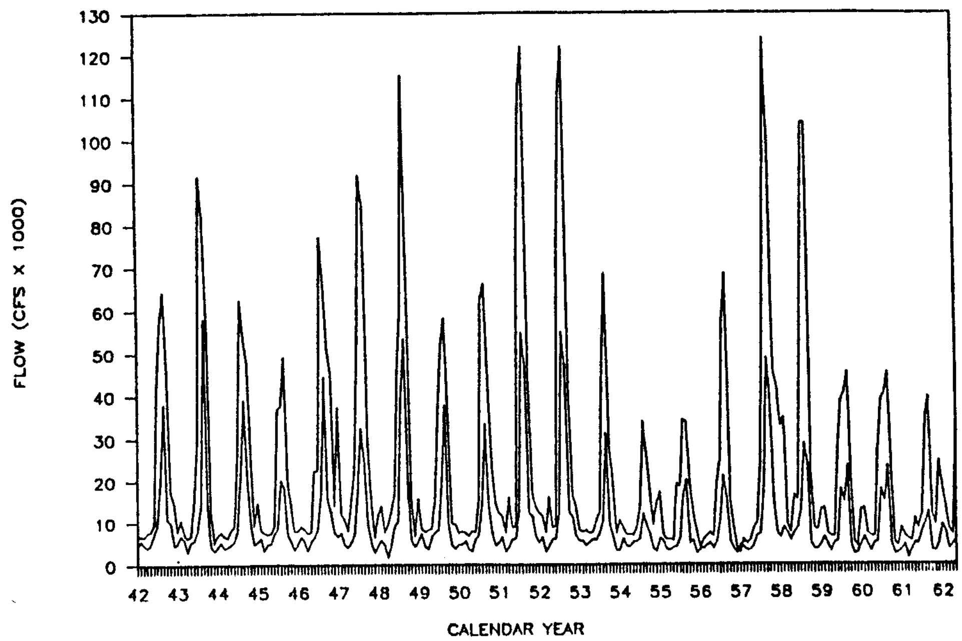
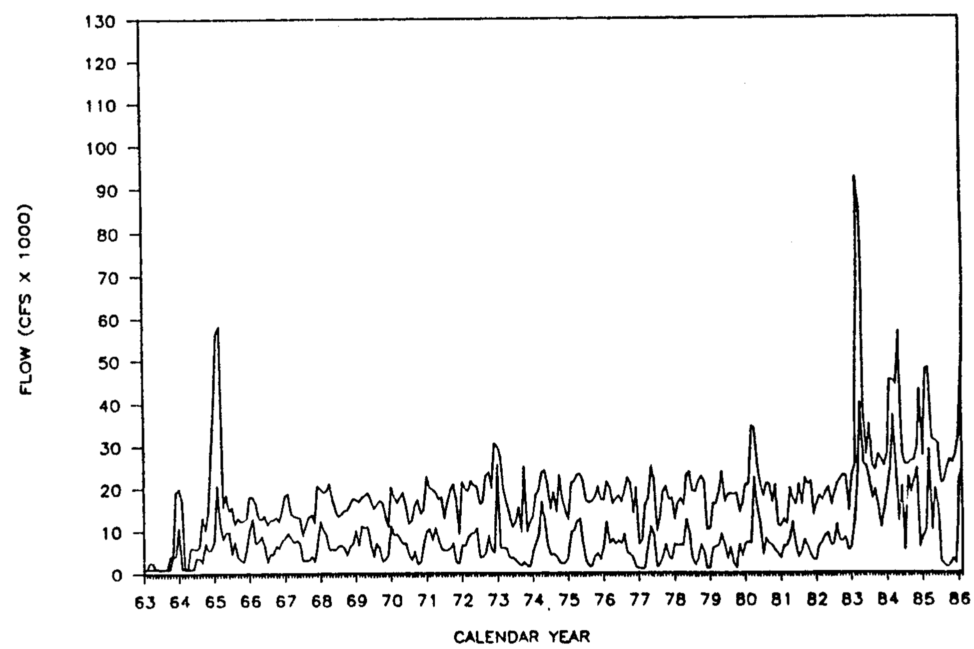


Figure 1. Colorado River drainage in the Southwest United States (from Carothers and Brown 1991).





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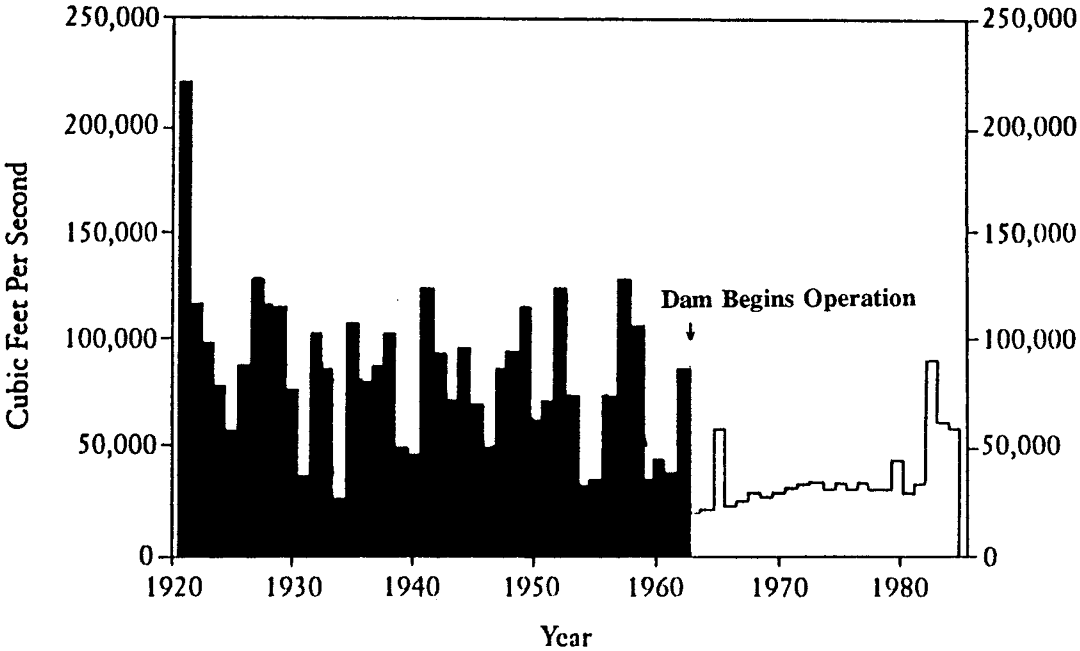

Figure 3. Annual peak flows (1920 - 1980's) of the Colorado River in Grand Canyon (from Carothers and Brown 1991).

occur in the Grand Canyon (Haden 1992). Overall, native fish have not fared well in their presence (Minckley 1991).

Eight species representing two families (Catostomidae and Cyprinidae) made up the original fish fauna within Marble and Grand Canyons (Glen Canyon Dam to Lake Mead). Only three species are still common: bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*Catostomus latipinnis*) and speckled dace (*Rhinichthys osculus*). Four species have been virtually extirpated: Colorado squawfish (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), bonytail chub (*Gila elegans*), and roundtail chub (*Gila robusta*). Humpback chub (*Gila cypha*) remain abundant only in and near the Little Colorado River (LCR) and are found in low densities throughout the Grand Canyon below the LCR (Minckley and Blinn 1976; Kaeding and Zimmerman 1983; Maddux et al. 1987). Four of the five latter species are listed federally as endangered species (roundtail chub is listed only as threatened by the state of Arizona). Six of the eight species (except bluehead sucker and speckled dace) are endemic to the Colorado River Basin (Minckley 1973; Minckley et al. 1986). The tributaries to the Colorado River in the Grand Canyon may provide the last stronghold for the remaining native fishes in this area (Suttkus and Clemmer 1976).

Shinumo Creek is one tributary that has been protected from many of the changes that have taken place in the Colorado River. Access to the creek is blocked near the mouth by an impassable waterfall (> 2-m drop). Therefore, Shinumo Creek has not experienced the invasion of many nonnative fishes that is characteristic of the Colorado River. The waterfall also precludes any direct impact on fish populations upstream from the decreased temperatures in the Colorado River. Despite this relative isolation, native fish have gained access to Shinumo Creek above the waterfall, probably during periods of exceptionally high flows in the Colorado River before dams were constructed. Rainbow trout (*Oncorhynchus mykiss*) have also become resident above the waterfall (through introductions by the National Park Service). Their presence gave me the opportunity to observe coexistence between native and exotic species.

The only previous records of fish present in Shinumo Creek came from the mouth, below the waterfall. I evaluated habitat availability and fish populations in Shinumo Creek at the confluence with the Colorado River and above the waterfall to 7 km upstream. Seasonal habitat availability was defined by measuring physical conditions in the creek. I also determined the seasonal distribution and relative abundance of fish populations.

SITE DESCRIPTION

Shinumo Creek enters the Colorado River at River Mile 108 (miles downstream from Lee's Ferry) at an elevation of 670 m (Figure 4). The creek flows about 18 km from the north rim of the Grand Canyon to the Colorado River (Figure 5). The main source of Shinumo Creek is South Big Springs located at an elevation of 2352 m. The average gradient of the stream overall is about 92 m/km; there is a drop of 44 m/km in the lower 7 km. The Shinumo drainage encompasses about 232 km^2 (calculated with Auto Cad program; USGS 1962), mostly within Grand Canyon National Park. Snowmelt from the north rim significantly increases discharge during the spring. Low flows (late summer and fall) range from 7 to 14 cubic feet per second (cfs), while spring runoff on one day in May 1990 was estimated at 57 cfs (USGS 1993). Temperatures range from summer highs of 27°C to winter lows of 3°C (Figure 6).

Shinumo Creek receives its water from the Muav Limestone of the Kaibab Plateau (Cole and Kubly 1976). It has relatively low salinity compared to other tributaries in the Canyon. It has high carbonate levels with more or less equal proportions of calcium and magnesium. The creek contains an extremely low N/P ratio due to both low nitrogen and high phosphorous (Cole and Kubly 1976). The pH during my study ranged from 8.2 to 8.8, with a mean of 8.5. Conductivity ranged from 193 to 361 microsiemens, with a mean of 309. Point samples from Shinumo Creek between May 1990 and March 1992 (USGS 1993), showed dissolved oxygen levels at or near 100% saturation between 7.4 and 9.7 mg/l.

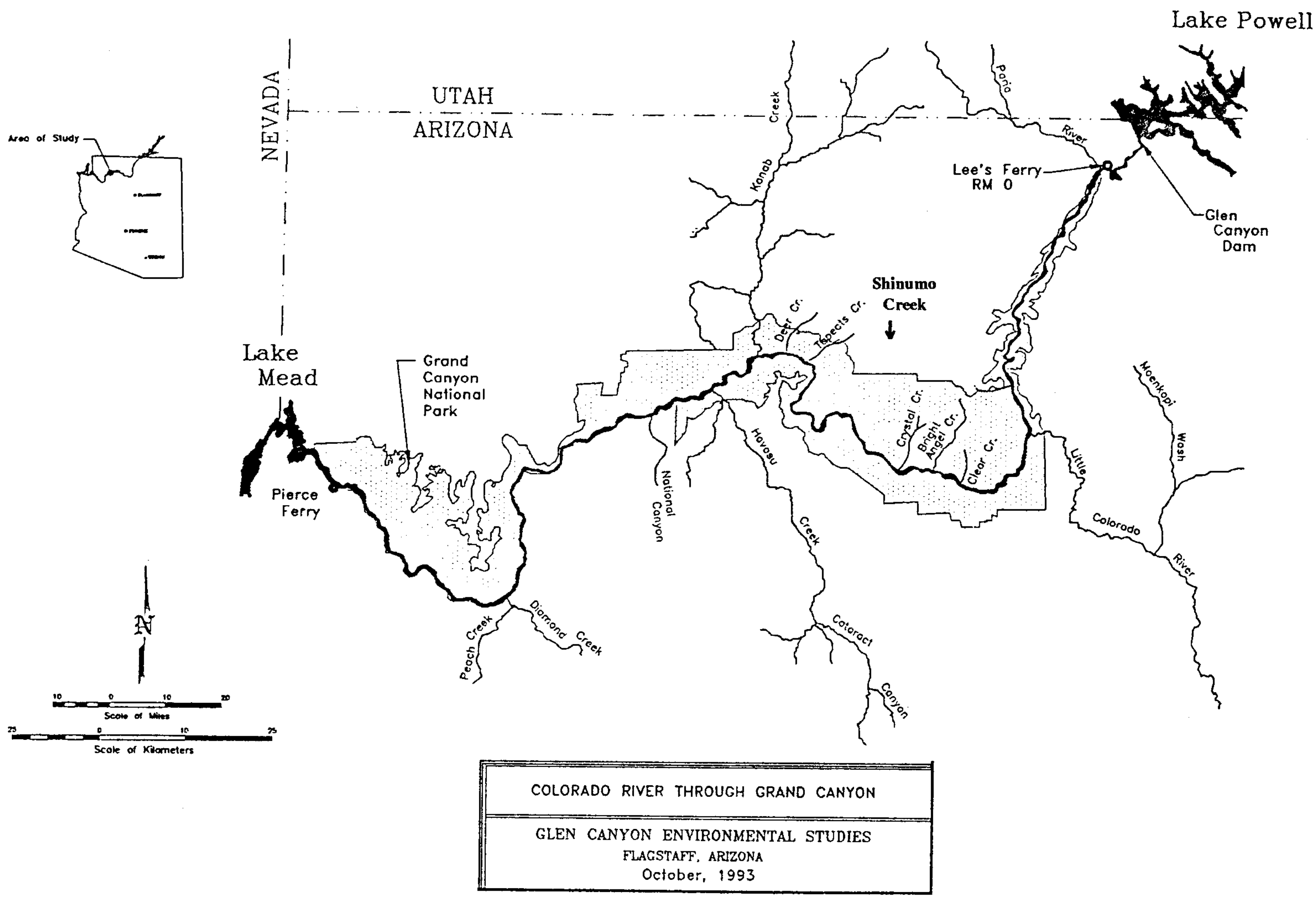

Figure 4. Colorado River within the Grand Canyon showing Shinumo Creek.

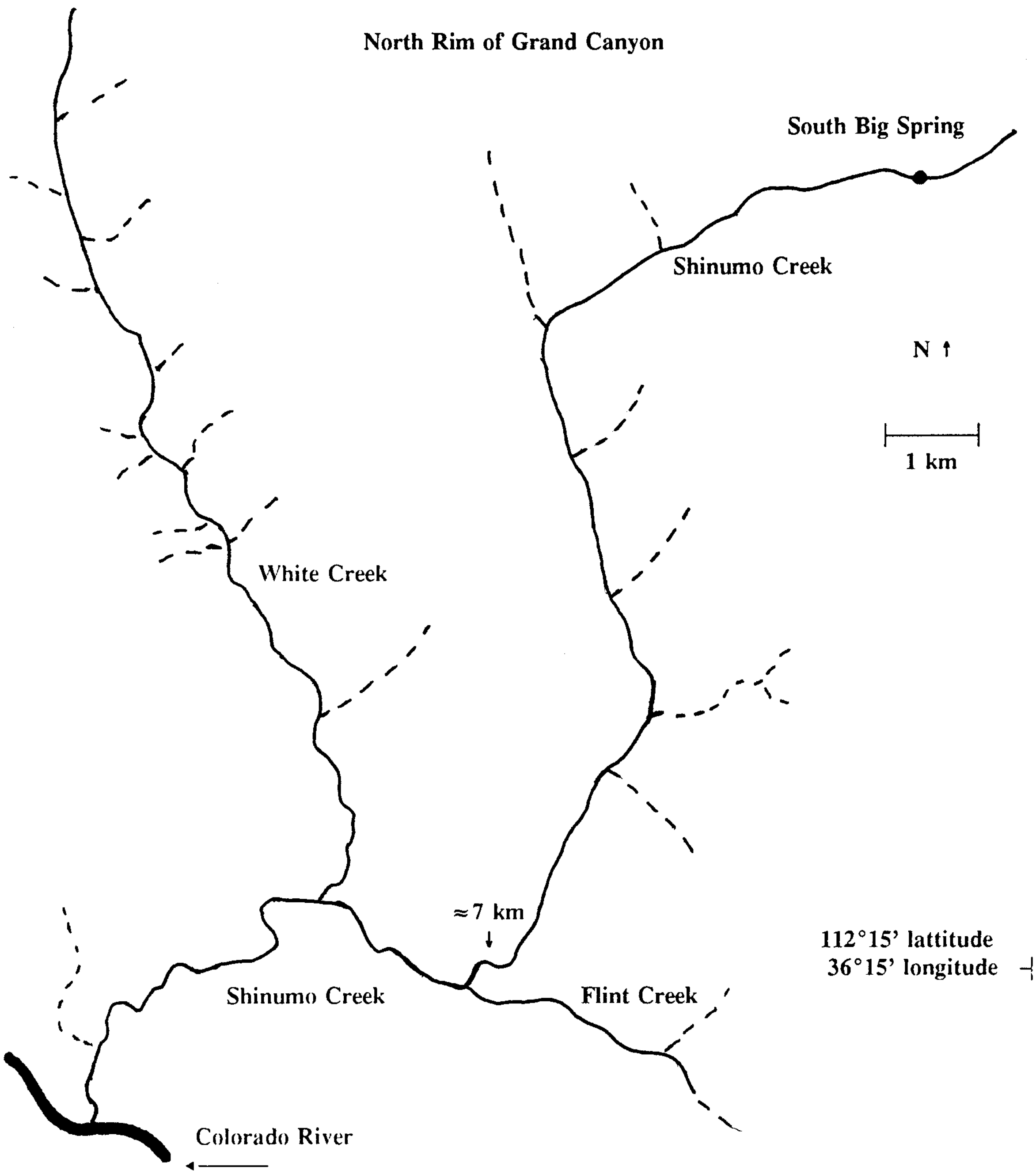

Figure 5. Shinumo Creek in the Grand Canyon (waterfall noted at 7 km upstream from the confluence with the Colorado River).

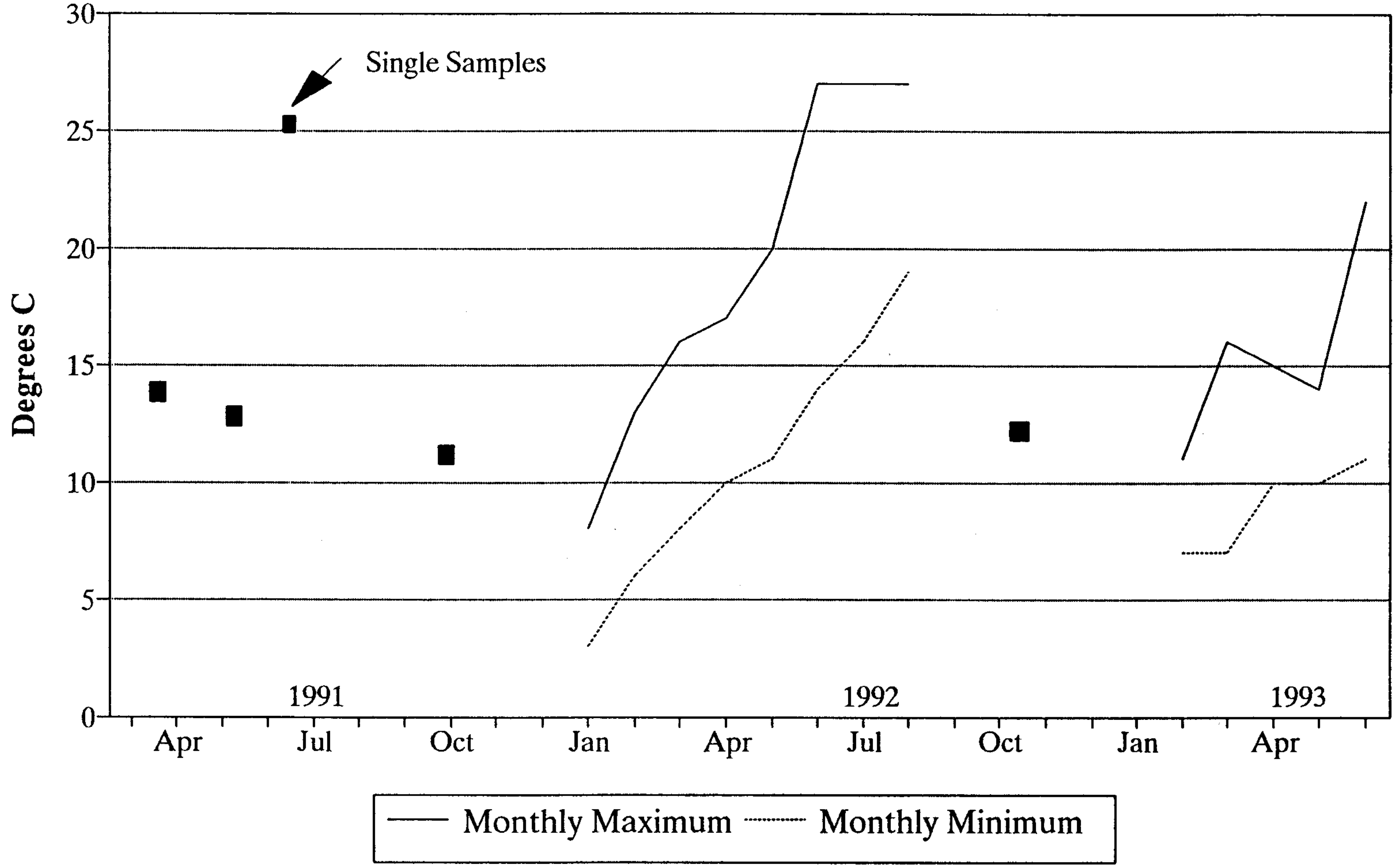

Figure 6. Temperatures, in degrees Celsius, for Shinumo Creek from March, 1991, to June, 1993 (Data from Glen Canyon Environmental Studies and U.S. Geological Survey).

Carbonate (CO_3^-) ranged from 8 to 25 mg/l (mean 14); bicarbonates (HCO_3^-) were from 174 to 303 mg/l (mean 230). Alkalinity, as $CaCO_3$, ranged from 160 to 302 mg/l (mean 232).

Where Shinumo Creek joins the Colorado River, a vertical waterfall over 2 m high (about 120 m upstream) forms a natural barrier to upstream movement of fish (except during extremely large Colorado River flows) (Figure 7). The creek in this confluence area is bounded on each side by vertical rock walls; the narrow channel is less than 10 m in width. Present fluctuations in the Colorado River inundate only this lower reach of Shinumo Creek.

Above the waterfall, Shinumo Canyon is considerably wider than many other tributaries in the Grand Canyon, probably reducing impacts of flooding events. The creek averages about 4 m wide. Dense overhanging vegetation often shades the entire channel. Substrates are dominated by sand and rock-cobble complexes. White Creek, a small perennial stream, joins Shinumo Creek from the west about 4.5 km upstream from the Colorado River. Flint Creek enters from the east near 7 km upstream (Figure 5). Another significant waterfall, a 2-m vertical drop, occurs at about 6.9 km upstream. This waterfall is within a narrow granite gorge, and may be a barrier to fish movement at normal flows. However, it might be compromised at very high discharge.

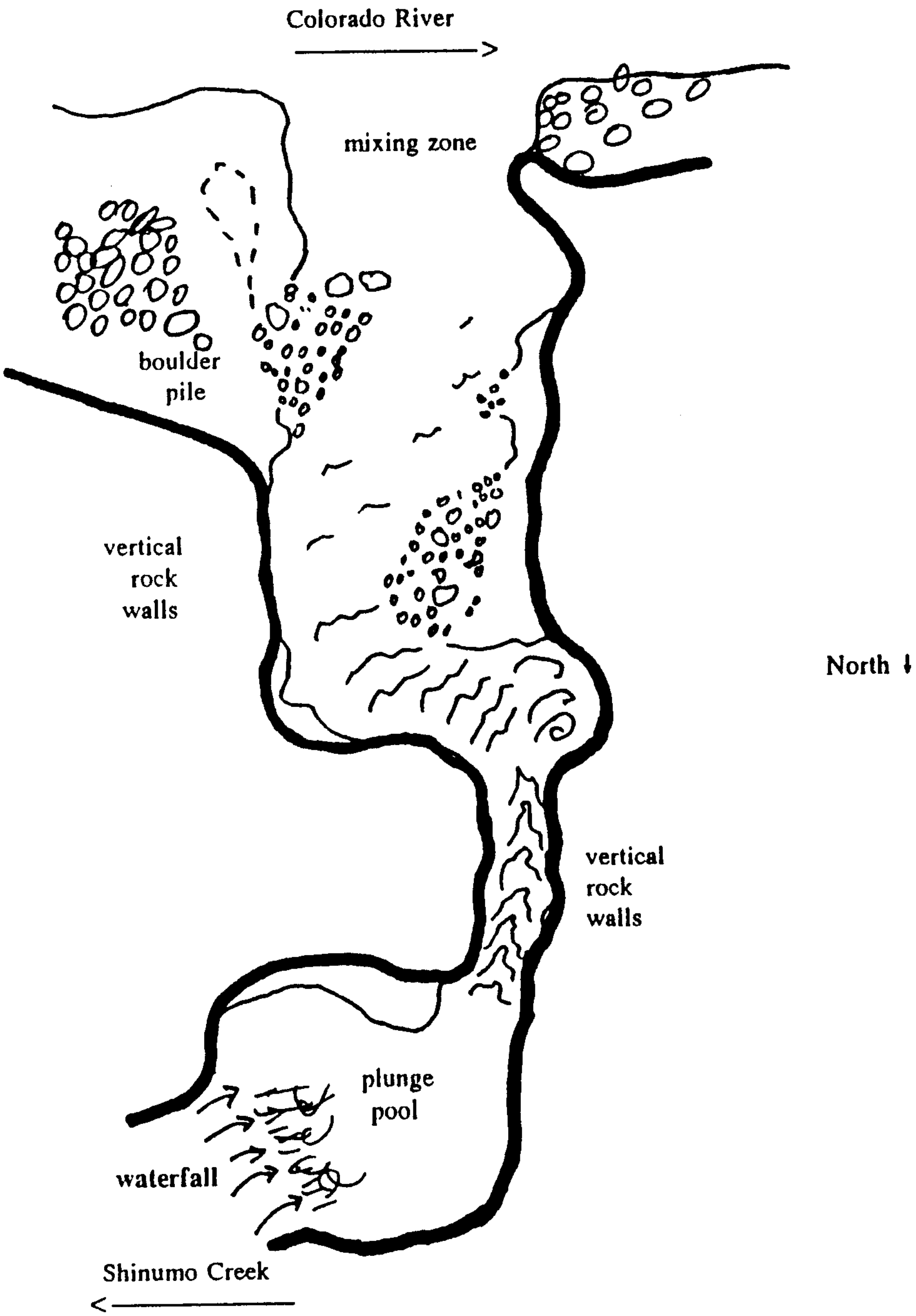

Figure 7. Confluence of Shinumo Creek and the Colorado River.

METHODS

Access to Shinumo Creek was via rafts provided by Glen Canyon Environmental Studies (GCES) and other research agencies. I also hiked into Shinumo Creek using the South Bass trail from the south rim, and I was ferried across the Colorado River by raft. I visited Shinumo Creek on July 31 to August 1, 1992; October 31 to November 1, 1992; January 8 to 10, 1993; March 13 to 16, 1993; and May, 1993. I could not collect data in May 12,1993, because of high flows on Shinumo Creek. Data also were collected for this study on June 22 and 23, 1993.

Habitat availability

Water depth and velocity and substrate particle size were measured at 1-m intervals across transects in Shinumo Creek. Permanent transects were established across the stream every 200 m beginning at the mouth and extending up to 10 km. This point-transect method has been widely used to analyze physical characteristics of stream habitats (Rinne 1985; Bovee 1986; Rahel and Hubert 1991; Olson-Rutz and Marlow 1992). Depth was measured to the nearest centimeter using a wading rod made of 3/4" PVC pipe. Water velocity was estimated as being in one of six categories (0 to 5), based on flow patterns around the wading rod (Table 1). These categories were calibrated by comparing patterns to appropriate mean water column velocities measured at 0.6x depth using a Marsh-McBirney flowmeter. Category estimates may not be completely consistent due to observer bias but are

Table 1. Water velocity categories (Gorman and Karr 1978) used for Shinumo Creek.

Category	Description	Range (m/s)
0	zero	<0.02
1	very slow	0.02 - 0.10
2	slow	0.10 - 0.25
3	moderate	0.25 - 0.75
4	fast	0.75 - 1.25
5	torrential	>1.25

Table 2. Substrate categories (Gorman and Karr 1978) used for Shinumo Creek.

Category	Description	Particle size (mm)
0	silt	<0.06
1	silty-sand	0.06 - 0.1
2	sand	0.10 - 2.0
3	gravel	2.0 - 16.0
4	pebble	16.0 - 32.0
5	rock	32.0 - 100
6	cobble	100 - 256
7	boulder	256 - 1m
8	large boulder	1m - 3m
11	bedrock	bedrock

representative of relative trends in water velocities (Gorman and Karr 1978; Schlosser 1982; Gorman 1988). I also recorded the presence of eddies (where flow was not parallel to the stream channel) and plunges (where the water dropped in elevation). Substrates were divided into 10 categories (0 to 8, 11) (Table 2) using a scale modified from Cummins (1962) (Gorman 1988). Vegetation or algae substrates were added as separate categories. Stream width, bank characteristics and amount of overhanging structure also were recorded.

In July, 1992, transects were measured every 200 m from the confluence with the Colorado River up to 10.0 km. No systematic transects were measured during October, 1992. In January and March, 1993, 200-m transects were measured up to 6.8 km. In June, 1993, transects were measured up to 4.0 km and from 6 to 6.8 km.

Fish sampling upstream

I used underwater observations (snorkeling), seining and backpack electrofishing to sample fish. Turbid water conditions prevented consistent use of snorkeling during all sample periods. During the two summer samples, in July 1992, and June, 1993, Shinumo Creek was extremely clear; visibility was more than 3 m. Visibility was less than 1 m during the other three trips, and seines were used as the only fish sampling method. Snorkel surveys were done using two individuals moving upstream through sample sites. Each observer counted the numbers of individual fish seen. Fish were identified by species and size class. Snorkeling has been shown to be an effective method for surveying stream fish populations (Northcote and Wilke 1963; Goldstein 1978; Whitworth and Schmidt 1980; Gosse and Helm 1981; Schill and Griffith 1984). Seining was done by making one pass downstream through a study site into a preset block-seine at the lower end of the site. Both small mesh seines were retrieved to collect fish. All fish captured were weighed, measured to total length in millimeters (mm TL) and released at the capture location.

Data from June, 1993, were provided by the Arizona Fisheries Resources Office-Pinetop, U.S. Fish and Wildlife Service. Fish were sampled in June using snorkeling and backpack electrofishing (Table 3). Electrofishing was done with one person operating the gas-powered backpack electrofisher (Coffelt Mark-10, pulsed-DC) and two researchers retrieving stunned fish with a small mesh seine. Electrofishing was difficult because water clarity allowed fish to easily detect and flee from researchers (Bovee 1986).

Sample sites were initially selected systematically in August, 1992, at 2-km intervals (Table 3). However, not all of these sites could be seined in October due to inappropriate physical stream conditions. Seining sites were selected as near to the previous sites as possible. These sites were free of large rocks and plunges that hinder seining efficiency (Goldstein 1978). Several additional sample sites were seined in October to provide more information on fish populations. After I observed only speckled dace and rainbow trout above the waterfall at about 7 km, I limited 1993 samples to the lower 6.8 km. In June, 1993, many small homogenous habitat

Table 3. Catch per unit effort (CPUE = # fish / area, 10 m^2) for fish sampled in Shinumo Creek in 1992 and 1993.

Date yymmdd	Method used	Site R-km	Area m^2	Temp °C	# BHS	CPUE BHS	# SPD	CPUE SPD	# RBT	CPUE RBT
920731	snorkel	2.00	106.0	23	2	0.19	206	19.43	2	0.19
920731	seine	2.70	120.4		21	1.74	152	12.63	5	0.42
920731	snorkel	4.00	124.0	22	2	0.16	100	8.06	24	1.94
920801	snorkel	6.00	153.4	19	11	0.72	76	4.96	36	2.35
920801	snorkel	8.00	90.0	20	0	0.00	1	0.11	16	1.78
920801	snorkel	9.20	83.7	20	0	0.00	20	2.39	9	1.08
921031		0.70	27.0	12	1	0.37	23	8.52	2	0.74
921031		1.80	59.5	13	4	0.67	10	1.68	3	0.50
921031		2.00	86.4	14	3	0.35	8	0.93	1	0.12
921031		2.70	55.9	13	36	6.44	49	8.77	4	0.72
921031	seine	4.20	49.0	10	0	0.00	1	0.20	0	0.00
921101		4.70	78.0	11	0	0.00	0	0.00	1	0.13
921101		6.20	40.3	11	0	0.00	2	0.50	1	0.25
921101		6.95	36.0		0	0.00	0	0.00	0	0.00
921101		7.00	40.0	12	0	0.00	0	0.00	0	0.00
930109		0.42	38.4	8	0	0.00	0	0.00	0	0.00
930109		1.80	84.0	8	0	0.00	0	0.00	0	0.00
930109		2.00	109.2	8	0	0.00	0	0.00	0	0.00
930109	seine	2.70	59.8	8	0	0.00	0	0.00	1	0.17
930109		4.20	76.0	9	0	0.00	0	0.00	0	0.00
930109		4.70	147.4	8	0	0.00	0	0.00	0	0.00
930109		6.20	48.3	9	0	0.00	0	0.00	3	0.62
930110		6.60	48.4	9	0	0.00	0	0.00	0	0.00
930316		0.42	67.5	13	0	0.00	0	0.00	0	0.00
930316		0.70	90.1	13	0	0.00	0	0.00	0	0.00
930316		1.80	132.8		0	0.00	0	0.00	0	0.00
930316	seine	2.00	112.8		0	0.00	0	0.00	1	0.09
930315		4.20	83.6	13	0	0.00	0	0.00	0	0.00
930315		4.70	149.7	12	0	0.00	0	0.00	0	0.00
930314		6.20	47.2	12	0	0.00	0	0.00	0	0.00
930314		6.60	49.5	11	0	0.00	0	0.00	0	0.00

Table 3 *continued*. Catch per unit effort (CPUE = # fish / area, $10m^2$) for fish sampled in Shinumo Creek in 1992 and 1993.

Date yymmdd	Method used	Site R-km	Area m^2	Temp °C	# BHS	CPUE BHS	# SPD	CPUE SPD	# RBT	CPUE RBT
930622	electrofish	0.25	4.0		0	0.00	2	5.00	0	0.00
930622	electrofish	0.26	6.0		0	0.00	1	1.67	1	1.67
930622	electrofish	0.29	8.0		0	0.00	1	1.25	0	0.00
930622	electrofish	0.30	24.0		0	0.00	4	1.67	1	0.42
930622	electrofish	0.70	70.7		1	0.03	8	0.23	2	0.06
930622	electrofish	0.80	5.4		1	1.84	2	3.68	1	1.84
930622	electrofish	0.81	9.0		0	0.00	1	1.11	0	0.00
930622	electrofish	0.82	15.0		0	0.00	1	0.67	1	0.67
930622	electrofish	0.83	7.6		0	0.00	0	0.00	1	1.32
930622	electrofish	0.90	14.5		0	0.00	2	1.38	1	0.69
930622	electrofish	1.70	24.0		2	0.83	3	1.25	0	0.00
930622	electrofish	1.75	5.3		0	0.00	1	1.88	0	0.00
930622	electrofish	1.80	7.7		0	0.00	3	3.90	0	0.00
930622	electrofish	1.85	13.8		0	0.00	2	1.45	0	0.00
930622	electrofish	1.90	28.0		0	0.00	2	0.71	2	0.71
930622	electrofish	1.98	9.0		0	0.00	1	1.11	2	2.22
930623	electrofish	1.99	18.2		1	0.57	2	1.14	0	0.00
930623	electrofish	2.00	6.0		0	0.00	1	1.67	2	3.33
930623	electrofish	2.05	13.0		0	0.00	0	0.00	1	0.77
930623	snorkel	2.10	47.0		3	0.64	4	0.85	6	1.28
930623	electrofish	2.10	"		1	0.21	1	0.21	2	0.43
930623	electrofish	2.70	125.0		4	0.32	4	0.32	3	0.24
930623	electrofish	2.72	64.2		2	0.31	2	0.31	0	0.00
930623	snorkel	2.76	56.1		9	1.60	40	7.13	10	1.78
930623	snorkel	2.78	32.0		1	0.31	1	0.31	9	2.81
930623	snorkel	4.00	63.0		4	0.63	50	7.93	16	2.54
930623	electrofish	4.03	12.9		0	1.55	2	1.55	0	0.00
930623	electrofish	4.04	6.4		0	1.56	1	1.56	0	0.00
930623	electrofish	4.05	8.0		0	2.50	2	2.50	1	1.25
930623	electrofish	4.07	18.0		1	0.00	0	0.00	8	4.44
930623	snorkel	4.70	122.0	17	12	0.98	50	4.10	24	1.97
930623	snorkel	6.0	70.0	19	3	0.43	40	5.71	16	2.29

patches (approximating the varying habitat conditions in the stream) were sampled for fish (Table 3).

In order to characterize the physical conditions where fish were sampled, depth, velocity and substrate were measured at 1-m intervals across transects at fish sample sites (Rinne 1985; Gorman 1988; Leonard and Orth 1988). Three transects were measured within each site at regular intervals (transects were a maximum of 10 m apart). If sample sites were longer than 30 m, additional transects were measured at 10-m intervals. Habitat measurements were made following exactly the same procedures as used on systematic transects (as described above). At each sample site, temperature, pH and conductivity were also measured using an ICM Water Analyzer.

Sampling below the waterfall

Below the waterfall, physical habitat variables were measured and fish were sampled in July, 1992, January, March and June, 1993. Transects were located every 20 m from the Colorado River up to the waterfall. Fish were sampled using snorkeling, seining, standard minnow traps, and mini-hoopnets (1 m x 50 cm x 1/4" mesh). Physical habitat conditions were also measured in areas where minnow traps and hoop nets were set (Gorman 1992). The three variables were measured (as previously described) in a uniform grid around the traps. Habitat data were taken from 16 points, spaced 25 cm apart around minnow traps and 20 points, spaced 50 cm apart, around hoop nets.

DATA ANALYSIS

Habitat availability data

Kolmogorov-Smirnov (K-S) tests (two-sample, two-sided) were used to compare distributions of physical habitat variables (depth, velocity and substrate) during each sample period between sites selected for fish sampling and the 200-m transects. The null hypothesis (H_o) for each test was that there was no difference in the two distributions. The K-S test involves calculating the maximum absolute difference (MAD) between two relative cumulative frequency distributions. The MAD is compared to tabled critical values based on the sample sizes of each distribution. If the MAD is greater than the critical value ($p < 0.05$), the null hypothesis is rejected (Gibbons 1985). Conover (1971) lists four basic assumptions of the K-S test: 1) the samples are random, 2) the two samples are mutually independent, 3) the data are at least on an ordinal scale and 4) variables are continuous. The test is also valid for discrete variables, but results will be conservative. Each data point was treated as an individual case. Points where depth equaled zero were omitted from calculations because dry areas do not constitute available habitat. K-S tests, and all other analysis, were done using the SPSS statistical program (SPSS release 4.1 for VMS/VAX).

In addition, Mann-Whitney (M-W) Rank Sum tests were also used to test for differences in depth within sample periods between the two data sets. M-W (two-sample, two-sided, rank sum) also tests differences in two distributions. The null hypothesis is that two distributions are not significantly different. Variables must be continuous to use the M-W test (Conover 1971), therefore, it was only used to analyze depths. The test statistic for the M-W test is calculated using the sum of the ranks of the smaller population and the two sample sizes (Gibbons 1985).

I used relative percent frequency histograms of distributions of depth, velocity, and substrate to estimate physical conditions available in Shinumo Creek. Data collected from systematic transects and fish sampling sites are included in these figures for July, 1992, January and March, 1993. Only transects within fish sample sites were included for October, 1993 (no 200-m transects were measured due to time constraints). Graphs for June, 1993, were separated for points along 200-m transects and transects within sample sites. Depths were grouped by 20-cm intervals.

K-S tests were also used to determine if distributions of single habitat variables were significantly different between sample periods. Data from each sample period were compared individually to data from every other sample period. I ran tests using only data collected from transects between 0.14 and 6.9 km upstream (above the lower waterfall and below the waterfall at 7 km). Habitat data from fish sample sites and systematic transects were pooled within sample periods, except for June, 1993, data (only systematic transects were used). Kruskal-Wallis (K-W) multiple-sample tests were used to test whether there were significant differences in depth between all sample periods. The K-W test is an extension of the M-W test, appropriate for multiple samples. The null hypothesis is that at least two of the multiple distributions are significantly different from each other.

Fish capture data

Relative abundance estimates were calculated for samples in July and October 1992, and June 1993. The relative percent occurrence is the number of individuals of a species observed or captured divided by the total number of fish seen in that sample period.

Catch per unit effort (CPUE) for fish was calculated at each sample site. The number of each species captured, or observed by snorkeling, was divided by the total area (length x width of the site) sampled and multiplied by ten (CPUE = total fish captured per 10 m^2). These indices are presented in histograms by sample period for bluehead sucker, speckled dace and rainbow trout. Data for bluehead sucker were not grouped by size class because few fish were not classified as adults. These data were pooled by sample period by using the sum of the fish caught divided by the sum of the areas sampled for each trip. Overall CPUE by sample method (snorkeling, seines and electrofishing were also developed into histograms for each species encountered above the waterfall. This provided a general comparison of fish sample techniques on Shinumo Creek.

I developed length-frequency histograms for bluehead sucker and rainbow trout captured in July and October, 1992, and June, 1993. Total lengths of bluehead sucker were grouped by 10-mm intervals. Rainbow trout lengths were grouped by 20-mm intervals.

RESULTS

Habitat availability

Habitat availability (depth, velocity and substrate) was measured along all transects (Table 4). In 8 of 9 K-S tests (June, 1993, data omitted), there were no significant differences between distributions of data from 200-m transect compared with data from transects at fish sample sites ($p > 0.05$) (Table 5). K-S tests on the data from June, 1993, resulted in significant differences in depth and substrates. Three of four M-W tests comparing depth at fish sample sites to those at 200-m transects also showed no difference ($p > 0.05$). Depths from fish sample sites in June, 1993, were significantly different (M-W tests, $p < 0.01$) from the overall habitat availability measured on that trip. In general, these results suggest that the sites selected to sample fish were not significantly different in the distributions of depth, velocity and substrate. However, in June, 1993, fish sample sites were deeper and had smaller substrates than did systematic transects (Figures 12 and 13) and in March, 1993, substrates were smaller at fish sample sites than at 200-m transects (Table 5). Therefore, data for the two sets of transects were pooled within sample periods (except for June, 1993) to make comparisons of seasonal habitat availability. These data were then used for K-S tests between sample periods.

K-S tests comparing distributions of depth, velocity and substrate between seasons resulted in 14 of 30 significant differences ($p < 0.05$) (Table 6). Two of 10 tests on depth, 5 of 10 tests on velocity and 7 of 10 tests on substrate were significantly different. K-W tests on depth resulted in no significant difference

Table 4. Summary of physical habitat data collected from Shinumo Creek.

Sample Period	Total of all samples		From 0.14 - 6.9 km	
	No. of 200-m transects (points)	Fish sample sites transects (points)	No. of 200-m transects (points)	Fish sample sites transects (points)
July 1992	46 (270)	35 (193)	31 (176)	17 (84)
Oct 1992	*none*	28 (137)	*none*	22 (105)
Jan 1993	30 (187)	28 (155)	29 (170)	28 (155)
Mar 1993	33 (235)	26 (169)	26 (186)	26 (169)
June 1993	39 (235)	197 (757)	39 (235)	197 (757)

Table 5. Comparison of habitat variables in Shinumo Creek collected along 200-m transects vs. transects within fish sample sites (Kolmogorov-Smirnov tests).

Variable	Sample	Max Abs Diff	p value	H_0:
DEPTH	July '92	0.1203	0.077	Accept
	Jan '93	0.0211	1.0	Accept
	Mar '93	0.0723	0.68	Accept
	June '93	0.1952	<0.001	Reject
VELOCITY	July '92	0.0366	0.99	Accept
	Jan '93	0.0716	0.78	Accept
	Mar '93	0.0956	0.33	Accept
	June '93	0.0548	0.65	Accept
SUBSTRATE	July '92	0.0838	0.41	Accept
	Jan '93	0.1148	0.21	Accept
	Mar '93	0.1861	0.002	Reject
	June '93	0.2261	<0.001	Reject

Table 6. Comparison of habitat availability data (distributions of depth, velocity and substrate) between sample periods in Shinumo Creek (Kolmogorov-Smirnov tests).

Samples Compared	DEPTH			VELOCITY			SUBSTRATE		
	MAD	**p val**	**H_o**	**MAD**	**p val**	**H_o**	**MAD**	**p val**	**H_o**
Jul'92 vs Oct'92	0.148	0.06	Accept	0.085	0.60	Accept	0.065	0.87	Accept
Jul'92 vs Jan'93	0.086	0.23	Accept	0.124	0.02	Reject	0.146	0.01	Reject
Jul'92 vs Mar'93	0.082	0.26	Accept	0.183	<0.001	Reject	0.080	0.30	Accept
Jul'92 vs Jun'93	0.082	0.39	Accept	0.122	0.053	Accept	0.273	<0.001	Reject
Oct'92 vs Jan'93	0.120	0.16	Accept	0.209	0.01	Reject	0.156	0.03	Reject
Oct'92 vs Mar'93	0.149	0.04	Reject	0.239	<0.001	Reject	0.094	0.41	Accept
Oct'92 vs Jun'93	0.166	0.02	Reject	0.169	0.01	Reject	0.319	<0.001	Reject
Jan'93 vs Mar'93	0.046	0.87	Accept	0.092	0.12	Accept	0.144	0.01	Reject
Jan'93 vs Jun'93	0.069	0.53	Accept	0.085	0.27	Accept	0.435	<0.001	Reject
Mar'93 vs Jun'93	0.044	0.94	Accept	0.098	0.13	Accept	0.369	<0.001	Reject

between all 5 sample periods ($p = 0.16$). Only points at transects between 0.14 and 6.9 km upstream were used in these comparisons so that seasonal variation would not be due to a difference in the stream reaches measured (see Table 4 for sample sizes). Only the systematic transects were included for June, 1993, because of the significant differences between the systematic transect data and the data from transects within fish sample sites (described above).

Histograms of the relative percent frequency of each category of the variables suggest only moderate differences in physical conditions across seasons (Figure 8 - 13). Depths of less than 40 cm are most common, as are velocities of category three or less ($\leq$ 0.75 m/s). Substrates are scattered by particle sizes, except for an abundance of silty-sand during October, 1992, and March, 1993.

Distribution and abundance of fishes

Bluehead sucker, speckled dace and rainbow trout were the only species observed above the lower waterfall on Shinumo Creek (Table 7). Speckled dace was the most abundant species during each of the sample periods in which fish were captured (Table 8). Bluehead sucker and rainbow trout relative abundance seemed to depend on the sample method used. The fish community at the confluence was more diverse than above the waterfall (at the mouth) during various times of the year. In July, 1992, 4 native species and 5 introduced species were captured there (Table 7). The native and introduced fish species observed below the waterfall represent all of the species common in the mainstem Colorado River.

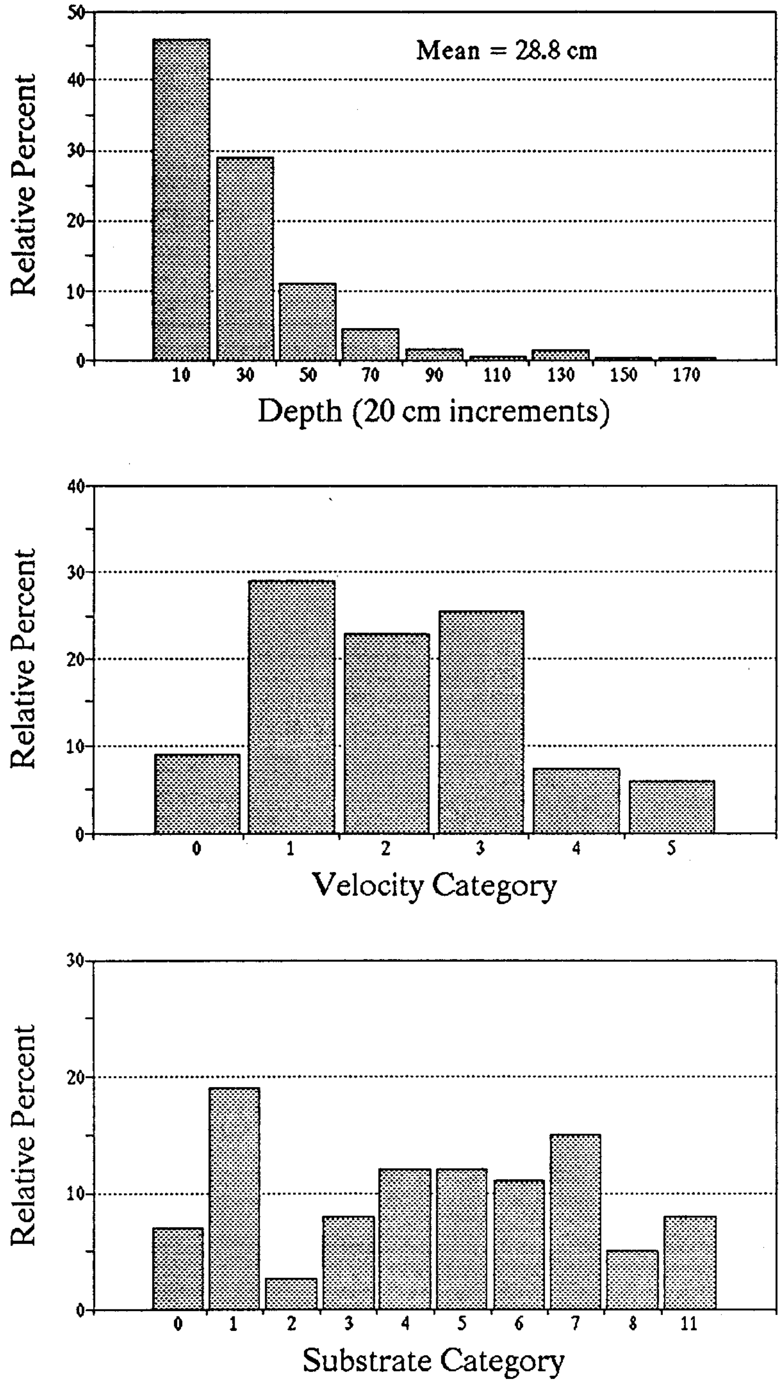

Figure 8. Relative percent of depth, velocity and substrate present in Shinumo Creek in July, 1992 (85 transects, 463 points).

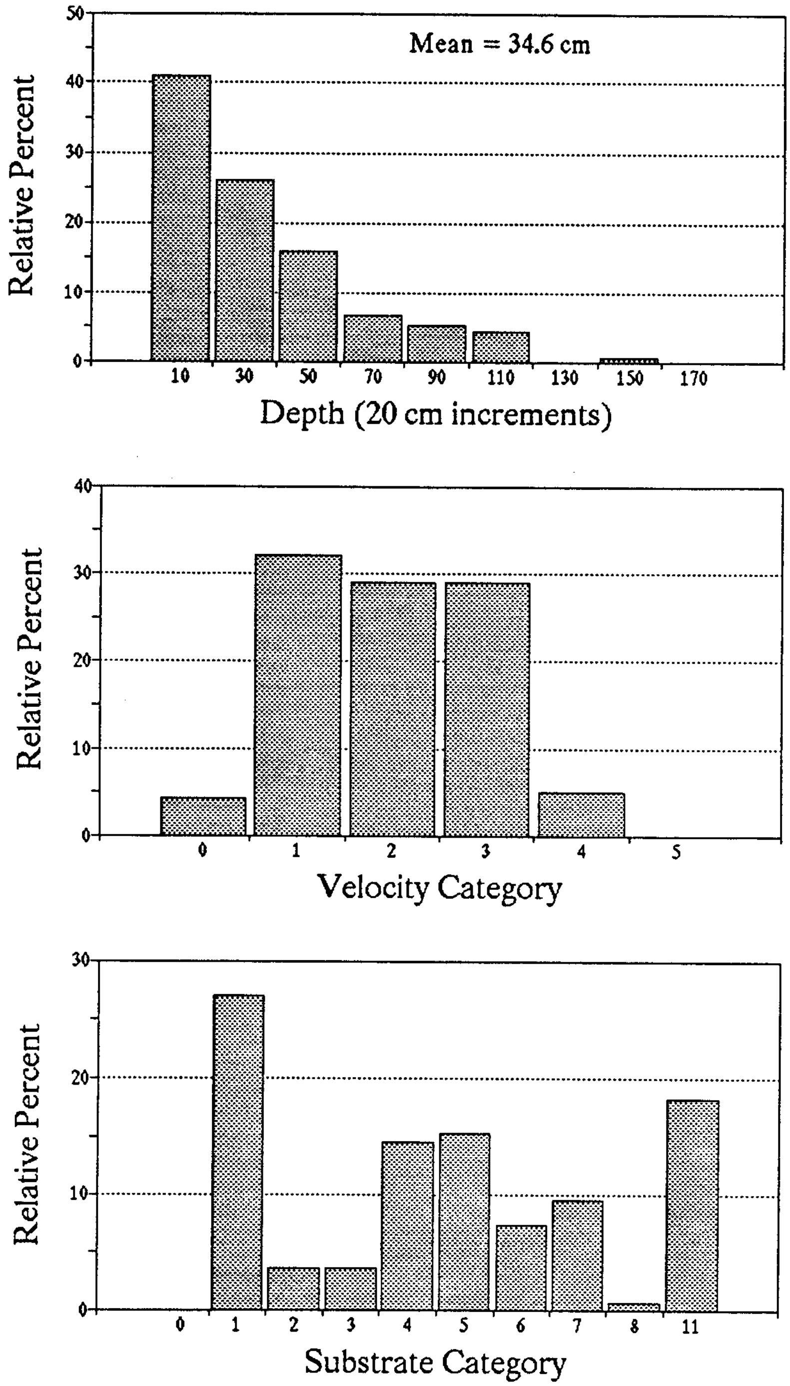

Figure 9. Relative percent of depth, velocity and substrate present in Shinumo Creek in October, 1992 (25 transects, 137 points).

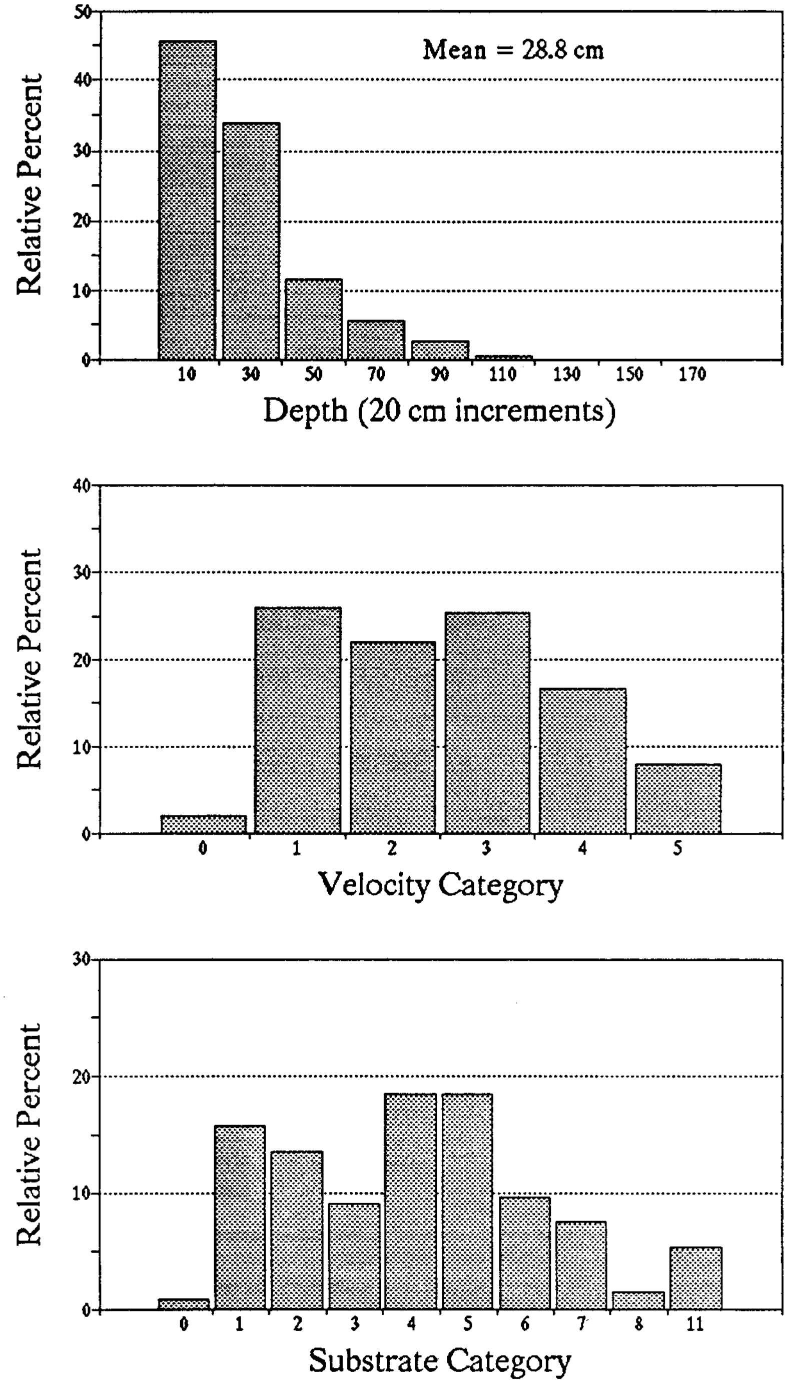

Figure 10. Relative percent of depth, velocity and substrate present in Shinumo Creek in January, 1993 (57 transects, 342 points).

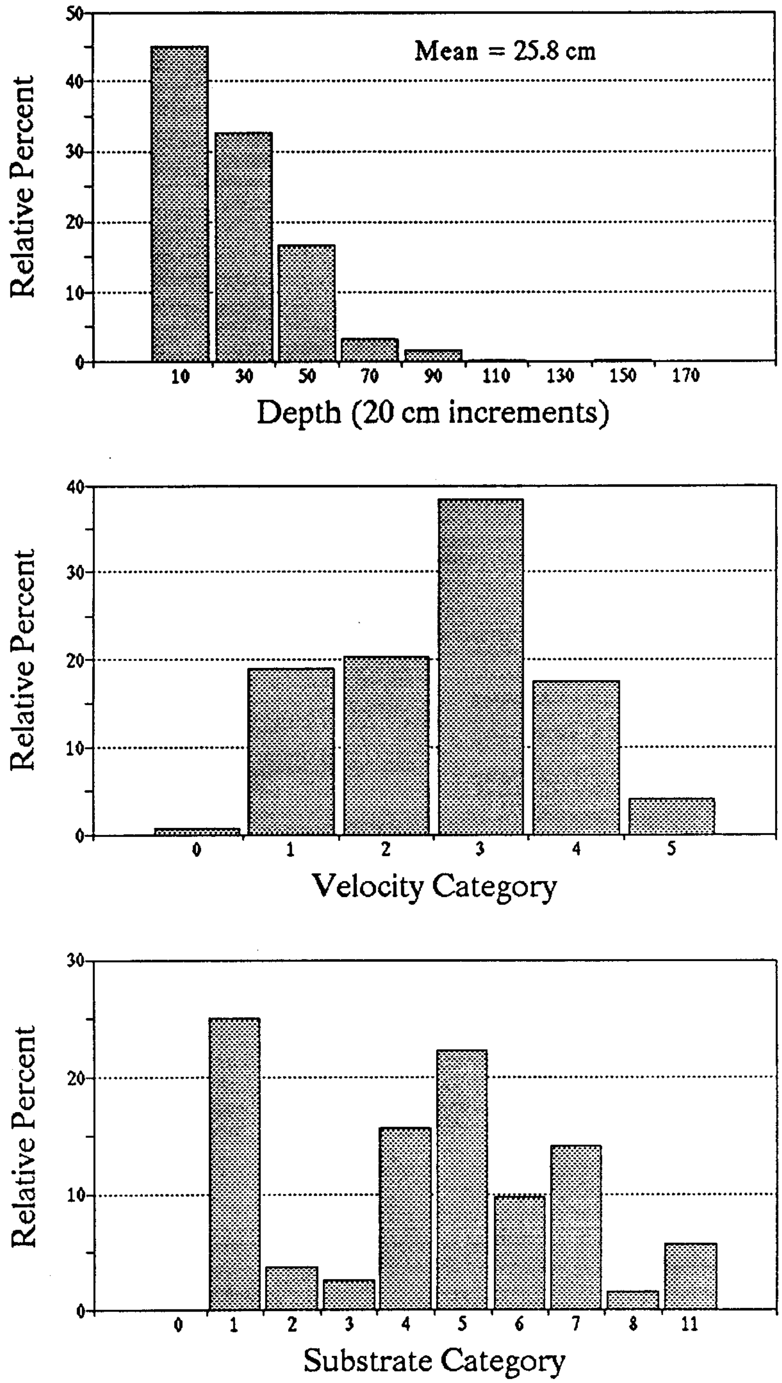

Figure 11. Relative percent of depth, velocity and substrate present in Shinumo Creek in March, 1993 (52 transects, 404 points).

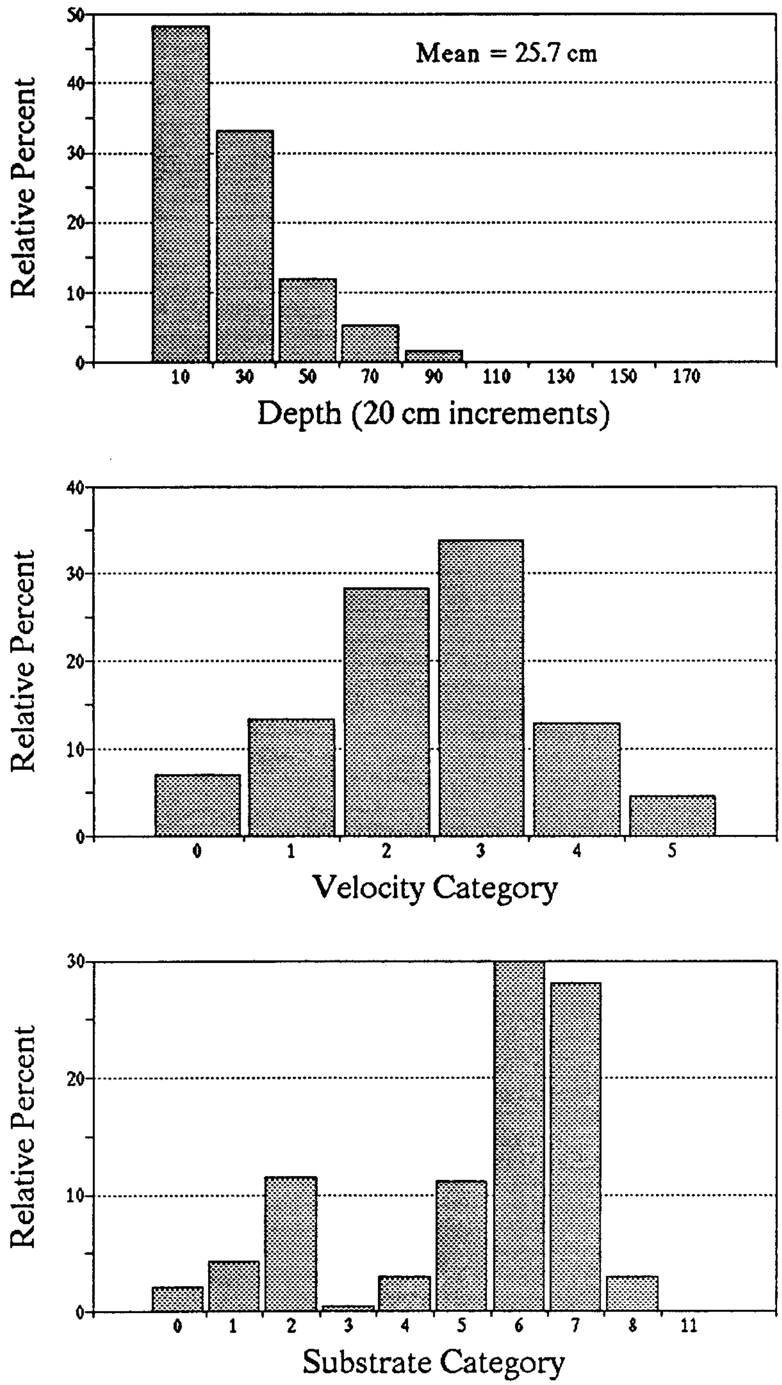

Figure 12. Relative percent of depth, velocity and substrate present in Shinumo Creek in June, 1993 (39 systematic transects, 235 points).

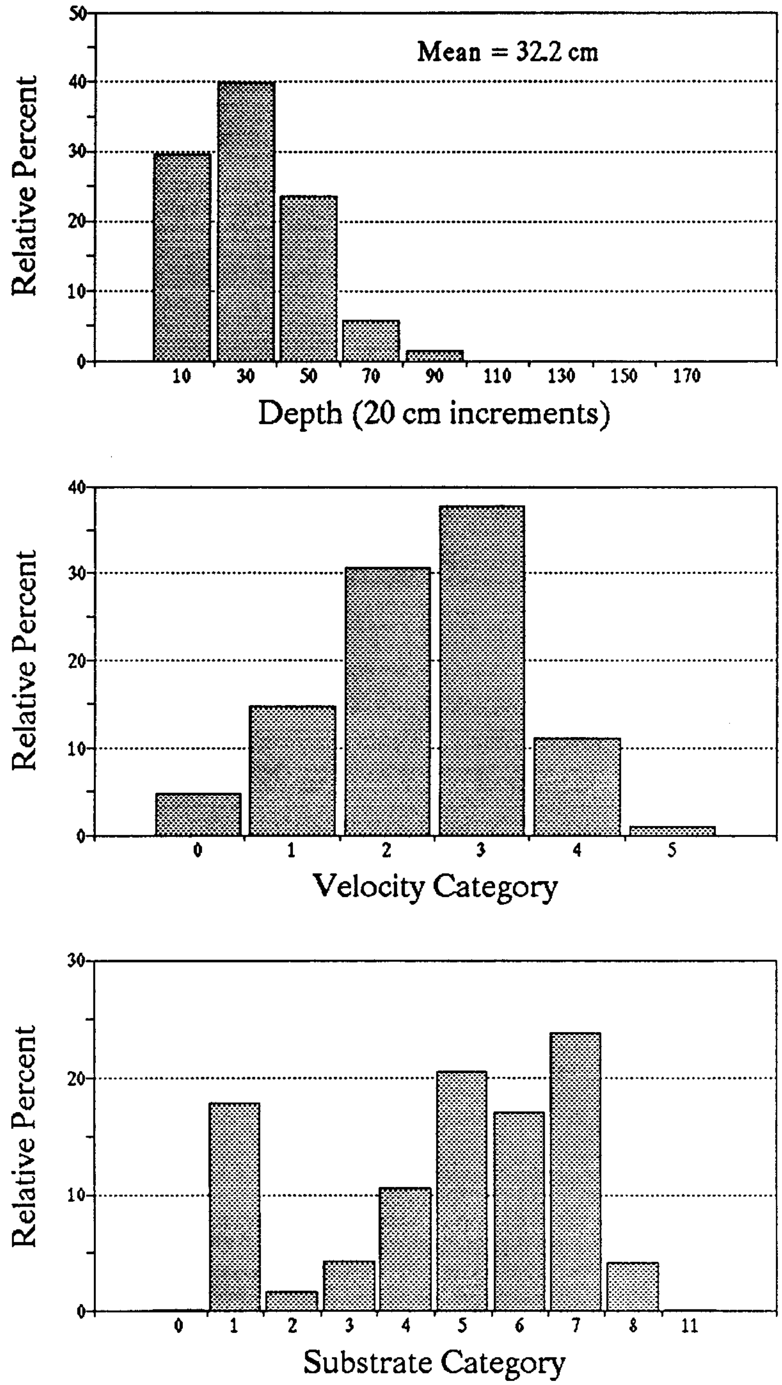

Figure 13. Relative percent of depth, velocity and substrate present in fish sample sites in Shinumo Creek in June, 1993 (197 transects, 757 points).

Table 7. Fish species encountered below and above the waterfall, 120 m upstream, in Shinumo Creek in 1992 and 1993 (**P** = present; ns = no sample).

DOWNSTREAM OF WATERFALL	Jul '92	Oct '92	Jan '93	Mar '93	June '93
Native:					
Gila Cypha, Humpback Chub	**P**	ns	-	ns	-
Catostomus latipinnis, Flannelmouth sucker	**P**	ns	-	ns	**P**
Catostomus discobolus, Bluehead sucker	**P**	ns	**P**	ns	**P**
Rhinichthys osculus, Speckled dace	**P**	ns	**P**	ns	**P**
Introduced:					
Oncorhynchus mykiss, Rainbow trout	**P**	ns	**P**	ns	**P**
Salmo trutta, Brown trout	**P**	ns	**P**	ns	**P**
Pimephales promelas, Fathead minnow	**P**	ns	-	ns	-
Cyprinus carpio, Common carp	**P**	ns	-	ns	-
Ictalurus punctatus, Channel catfish	**P**	ns	-	ns	-
UPSTREAM OF WATERFALL					
Native:					
Catostomus discobolus, Bluehead sucker	**P**	**P**	-	-	**P**
Rhinichthys osculus, Speckled dace	**P**	**P**	-	-	**P**
Introduced:					
Oncorhynchus mykiss, Rainbow trout	**P**	**P**	**P**	**P**	**P**

Table 8. Relative abundance (percent occurrence) of speckled dace (SPD), bluehead sucker (BHS), and rainbow trout (RBT) captured in Shinumo Creek.

Sample Period	Sample Methods	Total n	Percent SPD	Percent BHS	Percent RBT
July 1992	snorkel/ seines	683	81	5	13
Oct 1992	seines	149	62	30	8
June 1993	electrofish/ snorkel	389	47	17	36

CPUE graphs (Figure 14) show similar results in July, October, 1992, and June, 1993, although different methods were utilized. In January and March, 1993, no native species were encountered, even though identical methods were used and the same sites were sampled as in October, 1992 (Table 3). Snorkeling resulted in the highest catch for all three species (Figure 15). Capture of bluehead suckers with seines was higher than with electrofishing. Rainbow trout, however, were captured more frequently with electrofishing than with seines (Figure 15).

Total lengths of bluehead suckers ranged from 55 to 230 mm (mean = 160 mm; n = 77). Length-frequency graphs for bluehead sucker show a shift to larger mean total lengths from July to October, 1992 (Figure 16).

Total lengths of rainbow trout ranged from 62 to 300 mm (mean = 149 mm, n = 46) (Figure 17).

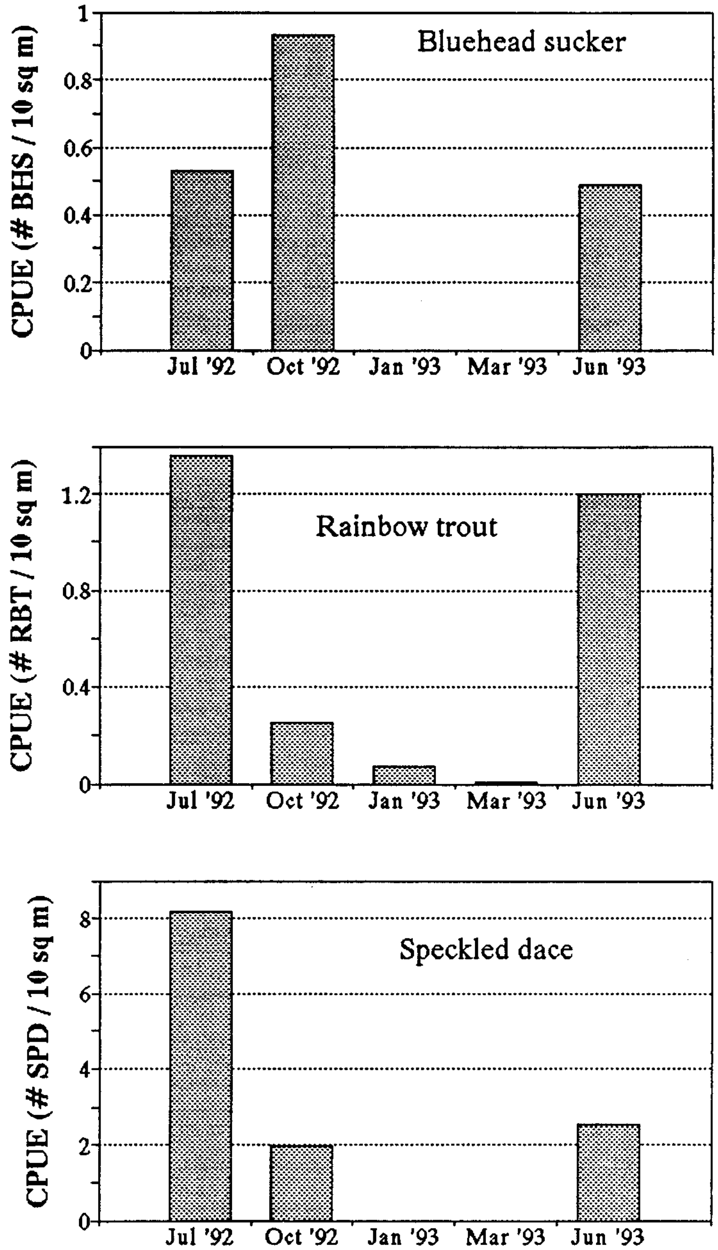

Figure 14. Catch per unit effort (CPUE) by seining (July and October, 1992, and January and March, 1993), snorkeling (July, 1992, and June, 1993) and electrofishing (June, 1993) for fish species upstream in Shinumo Creek.

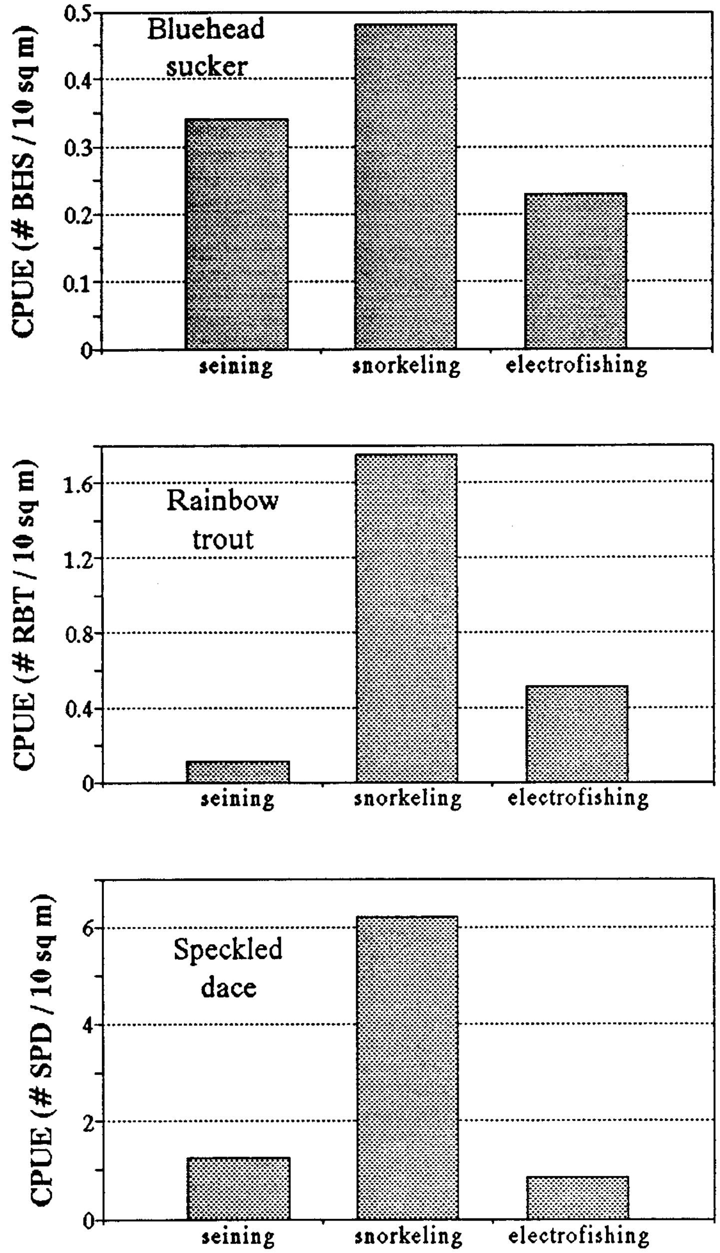

Figure 15. Overall catch per unit effort (CPUE) by sample method for fishes captured upstream in Shinumo Creek in 1992 and 1993.

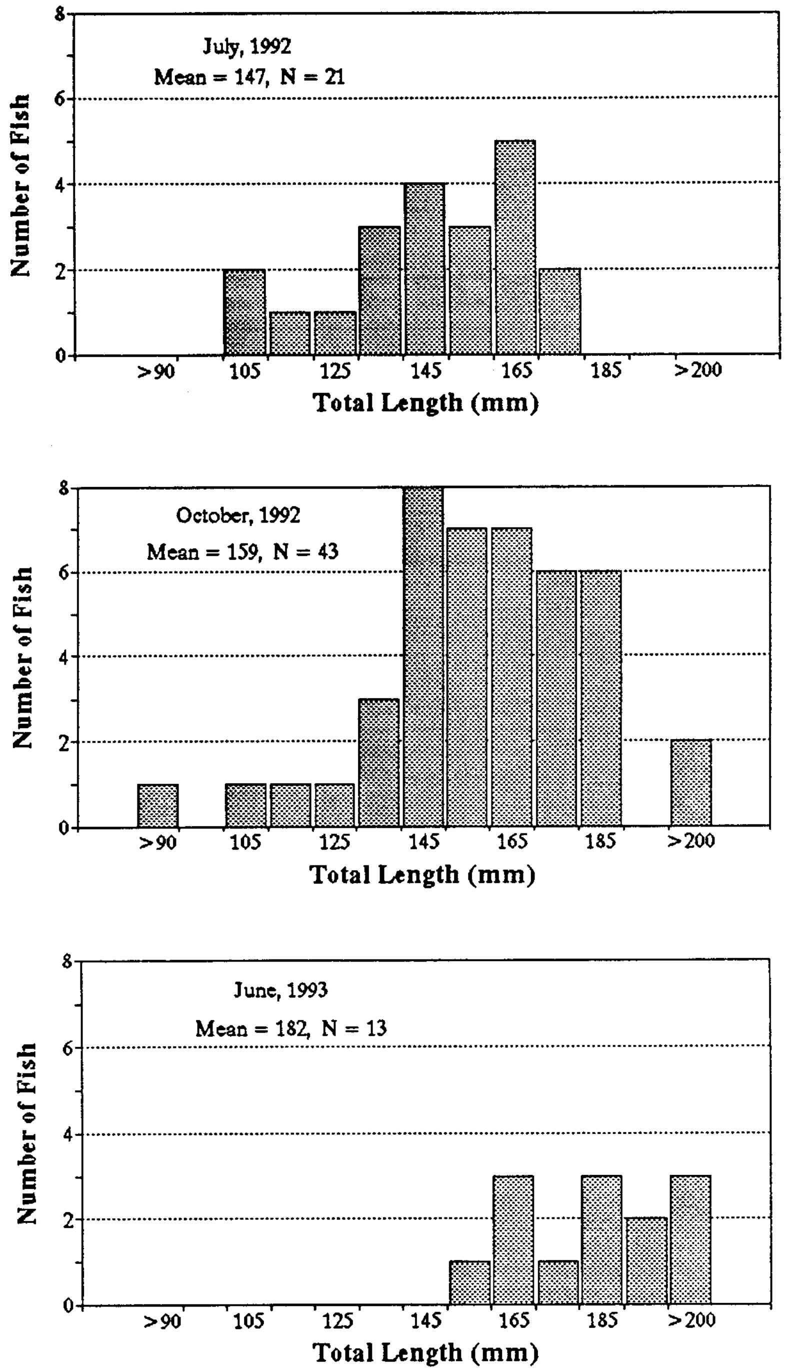

Figure 16. Length-frequency histograms for bluehead sucker in Shinumo Creek.

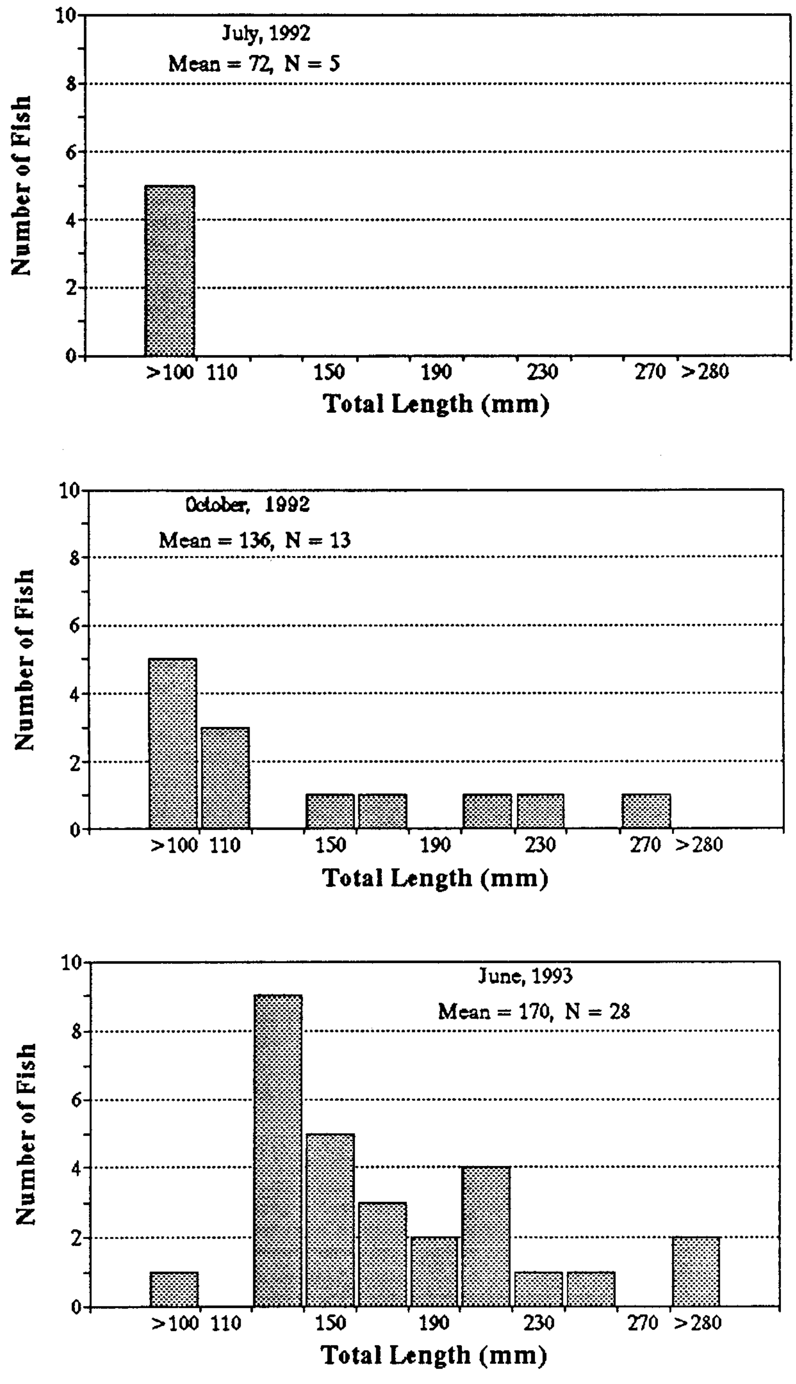

Figure 17. Length-frequency histograms for rainbow trout in Shinumo Creek.

DISCUSSION

Habitat availability in upstream areas

Shinumo Creek is a small, clear, coldwater stream with a high gradient. Pools up to about 1.5 m deep are created when water plunges over small boulders. Long riffles with pebble, rock and cobble substrate and depths less than 0.5 m are common. The stream has low discharge throughout the majority of the year. Banks are densely vegetated, providing significant shading and instream root complexes and undercut banks.

Results of K-S tests suggest that habitat availability changed over time on Shinumo Creek (Table 6). These differences may be explained by changes associated with variation in flows. The lowest flows occurred during the two summer trips and may account for differences detected in depth and velocity variables. The high degree of variation in the distributions of substrates across the samples during this period (7 of 10 tests were significant, Table 6) may reflect flood related displacement of smaller-sized substrate particles from some locations and their deposition in others. These data suggest that flood events can cause changes in depth, velocity and substrate in Shinumo Creek both seasonally and between years.

Large flood events are probably rare and of short duration because of the small drainage area. During October, 1992, an evening rain caused the water level to rise about 0.5 m overnight (about twice the volume later observed). However, by the next afternoon the creek had subsided to near the previous level. There is increased discharge during the spring and early summer. I observed high flows on

May 12, 1993, that were about 4 or 5 times the volume observed during the previous summer. The amount of precipitation in the high elevation drainage provides water from runoff, as well as determines aquifer levels that create the discharge of Shinumo Creek. The quantity of habitat available, therefore, is highly variable throughout the year.

Fish abundance upstream

Relative abundance estimates of the three species found upstream was variable between the sample periods (Table 8). However, estimates were developed using different sample methods that may not produce comparable results. For example, snorkling resulted in higher estimates of speckled dace than electrofishing because electrofishing tends to catch larger fish more efficiently (Reynolds 1983). Seining appeared to be a better method than electrofishing for capturing bluehead sucker while the opposite was found for rainbow trout (Figure 15).

No native fish were captured during winter and spring samples. It is possible that fish avoided the seines since the stream was less turbid in January and March, 1993, than in October, 1992 (the small flood made the water turbid). Clearer water could allow fish to see and avoid the nets. However, few or no native fish were seen during these two trips even though the water was relatively clear. Also, fish were captured by seines at one site in July, 1992, when the water was very clear (Table 3). Another possibility is that fish left the stream in the winter. It is not reasonable to hypothesize that fish emigrated from Shinumo Creek because they were present in the summer of 1993 and could not have returned to the creek from the Colorado River because of the waterfall at the mouth. Significantly decreased catch rates of bluehead sucker in the Colorado River during the winter was also found by Maddux et al. (1987).

A more probable explanation relates fish behavior to the lower water temperatures in January and March, 1993 (Table 3, Figure 6). During low water temperatures fish may position themselves beneath substrates for cover. This pattern has been demonstrated in a laboratory setting with the bayou darter (*Etheostoma rubrum*) (Ross et al. 1992) and by underwater observations of the tesselated darter (*Etheostoma olmstedi*) (Goldstein 1978), blacknose dace (*Rhinichthys atratulus*) (Cunjak and Power 1986a), brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*) (Cunjak and Power 1986b; Heggenes et al. 1993) and juvenile Atlantic salmon (*Salmo salar*) (Rimmer et al. 1984). If fish in Shinumo Creek displayed these behaviors, they would be difficult to capture at low temperatures with the techniques I used. Perhaps electrofishing or some method that included disrupting substrates (e.g. kick-seining) would be more efficient to sample fish populations in Shinumo Creek when water temperatures are low.

Distribution of native fishes

Bluehead sucker and speckled dace were the only native fish species above the waterfall (120 m upstream with the confluence of the Colorado River) in Shinumo Creek. Speckled dace were found as far as 9.2 km upstream but no bluehead sucker were observed above another waterfall at 7 km (Figure 5). This waterfall may be the upstream limit of the distribution of bluehead sucker in Shinumo Creek (Table 3). However, I sampled in these areas on only two occassions.

Both bluehead sucker and speckled dace are widely distributed species. Speckled dace are a native species common throughout western North America (Lee et al. 1980; Minckley et al. 1986). Bluehead sucker are found in the Upper Snake, Bear and Weber River drainages and throughout much of the Upper Colorado River drainage (Lee et al. 1980; Minckley et al. 1986; Sigler and Sigler 1987). Both species are also relatively common in the Grand Canyon reach of the Colorado River. Speckled dace are also abundant in most of the side streams in the Grand Canyon where trout are uncommon (personal observations). Bluehead sucker are common in Kanab (Otis 1993) and Havasu Creeks (personal observations). Also, the species is occasionally found in the Paria (Weiss 1993) and Little Colorado Rivers (Carothers and Minckley 1981; personal communication, Owen Gorman) and Bright Angel Creek (Otis 1993). Flannelmouth sucker and humpback chub occurred in Shinumo Creek only at the confluence with the Colorado River.

Historically, the traditional "big-river" species of the Colorado River (Colorado squawfish, razorback sucker, bonytail chub and humpback chub) may have had access to Shinumo Creek during high flows by the Colorado River prior to the closure of Glen Canyon Dam. However, these species were probably never resident or abundant there due to the different habitat conditions in Shinumo Creek compared to the Colorado River. The habitat requirements of these fish have typically been associated with the mainstem Colorado River (Holden and Stalkner 1975; Kaeding and Zimmerman 1983; Tyus and Karp 1989; Valdez et al. 1990), which was historically a large, silt-laden river. In contrast, Shinumo Creek is a small, clearwater, high-gradient stream.

Only two native fish species (bluehead sucker and speckled dace) appear to be residents of both the mainstem and the smaller tributaries within the Grand Canyon. Two other native species (flannelmouth sucker and humpback chub) use some tributaries to a limited extent. Humpback chub is common only in the Little Colorado River (Holden and Stalkner 1975), a system much larger than any of the other tributaries in the Grand Canyon. Flannnelmouth sucker appear to use the Paria River, Bright Angel Creek and, possibly, Kanab Creek only seasonally for spawning (Otis 1993; Weiss 1993). However, they are found throughout the year in the Little Colorado River. These four species that utilize the tributaries are the only native fish remaining in the Grand Canyon. Those species not associated with the tributaries (discussed above) have been virtually extirpated from the Grand Canyon (Carothers and Minckley 1981; Maddux et al. 1987). These observations suggest that the tributaries may play a vital role in sustaining the remaining native fishes in the Grand Canyon.

Distribution of introduced fish

Rainbow trout were found in Shinumo Creek at least as far upstream as 9.2 km (the furthest upstream of any fish sampling) (Table 3). Despite their relative abundance, I captured or observed few large rainbow trout (Figure 17).

Rainbow trout were introduced into the Grand Canyon for recreational fishing by Grand Canyon National Park as early as the 1920's (AGFD 1950; Strickland 1950) and were planted until the 1960's (Haden 1992). "Black-spotted trout" eggs were stocked in Shinumo Creek in 1925 and 1930 (Williamson and Tyler 1932; Persons et al. 1985). Minckley (1973) identifies "black-spotted" as a common name for rainbow trout (but not accurately identifiable) used in older records of trout stockings. These fish were most likely the origin of the current rainbow trout in Shinumo Creek. They were introduced there for recreational fishing purposes and have presumably maintained reproducing populations since that time. There may still be some limited use of Shinumo Creek for fishing, however, I did not encounter any recreational anglers during my study on Shinumo Creek.

Rainbow trout, brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*) and fathead minnow (*Pimephales promelas*) occurred below the first waterfall in Shinumo Creek. One brown trout was > 450 mm TL. These species are most likely residents of the Colorado River mainstem and are currently excluded from the upper parts of Shinumo Creek by the waterfall at the mouth.

Interactions of native and introduced fishes

Above the lower waterfall in Shinumo Creek, permanent populations of native (bluehead sucker, speckled dace) and introduced (rainbow trout) fish coexist. In other small streams tributary to the Colorado River in the Grand Canyon, resident fish communities are generally dominated exclusively by either introduced or native fish species. For example, samples taken in summer and winter during a concurrent study showed only rainbow trout in Tapeats Creek (Figure 4) (personal observations). Bright Angel Creek is currently dominated by brown and rainbow trout. Native fish (speckled dace, flannelmouth and bluehead sucker) occur in significant numbers only seasonally (Otis 1993). Kanab Creek (Figure 4) consistently contains only bluehead sucker and speckled dace upstream of the mouth (Otis 1993). The Paria River (upstream of the mouth) contains only speckled dace throughout the year and flannelmouth sucker are found only seasonally (Weiss 1993).

It is generally assumed that the presence of introduced fish species negatively impacts native fishes because the decline of native fish populations following the introduction of nonnative fishes has been a documented pattern (Deacon et al. 1964; Moyle and Nichols 1974; Schoenherr 1981; Moyle and Williams 1990; Minckley

1991; Rowe 1993). The mechanisms behind these patterns may involve competition for resources (Li 1975), predation or hybridization (Verspoor 1988; Ferguson 1990).

Researchers from the Grand Canyon suggest that trout have negatively affected native species populations. Maddux et al. (1987) found the relative frequency of all trout species was inversly proportional to the frequency of native species. Also, Minckley (1978) showed densities of bluehead sucker and speckled dace in Bright Angel Creek were inversely proportional to that of large rainbow trout (mean length = 371 mm TL; maximum = 613 mm TL) and suggested that replacement resulted from both competition for space and predation.

Competition for space may be of reduced importance in Shinumo Creek because of the similar size of the rainbow trout and bluehead suckers. A previous study of competitive interactions between coexisting Sacramento sucker (*Catostomus occidentalis*) and rainbow trout, suggested that there was little overlap in microhabitat use patterns (Baltz and Moyle 1984). When similar-sized individuals of the two species coexisted within the same areas, there was "strong vertical segregation" between them. In general, the suckers used areas near the bottom of the water column, while trout used areas higher in the water column (Baltz and Moyle 1984). However, underwater observations revealed that when large individuals of one species encountered smaller individuals of the other species, the smaller individuals would often be displaced (Baltz and Moyle 1984). It is possible that the similar-sized bluehead suckers and rainbow trout in Shinumo Creek display vertical segregation in microhabitat use patterns.

Studies have also suggested that predation by introduced fishes may be a leading cause of loss of native fishes (Meffe 1985; Marsh and Brooks 1989; Tyus and Beard 1990). Trout in particular have been implicated as predators on native fish (Minckley 1978; Marrin and Erman 1982). However, rainbow trout in the Grand Canyon generally feed on various invertebrates in the drift and benthos and on the filamentous alga, *Cladophora spp.* (Carothers and Minckley 1981; Maddux et al. 1987). Less than one percent of rainbow trout stomachs sampled by Maddux et al. (1987) contained fish remains ($n > 600$). However, absence of fish remains is not a conclusive indication of the absence of predation because predation may be occurring primarily on larval fish only at specific times of the year. Larval fish are digested quickly and few remains can be recovered (Tyus and Beard 1990).

Other studies indicate that rainbow trout may become piscivorous only after reaching sizes greater than or near 300 mm TL (Carlander 1969; Marrin and Erman 1982). In most of the other tributaries in the Grand Canyon where fish populations are dominated by trout (e.g., Tapeats and Bright Angel Creeks), large rainbow or brown trout periodically enter the tributaries from the Colorado River to spawn (personal observations; Minckley 1978; Otis 1993). In Bright Angel Creek, some large rainbow trout collected in the spring contained vertebrate remains (Minckley 1978). In circumstances where large trout coexist with native fish, both competition for space and predation may be important factors in the decline of native fish numbers (Minckley 1978).

A key factor in this discussion is the importance of the size of the fish in the competitive and predatory interactions. My data showed that no fish of any species reached sizes >300 mm TL in Shinumo Creek and that adults of both trout and bluehead suckers were of similar size (Figures 15 and 17). Therefore, the relatively small size of the trout in Shinumo Creek may allow coexistence of bluehead suckers and speckled dace by reducing competition and predation. I would not discount the possibility that rainbow trout prey on speckled dace or bluehead sucker during early life stages. However, my observations provide circumstantial evidence that such mortalities have not eliminated either population of native fish in Shinumo Creek.

Bluehead sucker ecology

Bluehead sucker (*Catostomus discobolus* Cope) was originally called the bluehead mountain-sucker (*Pantosteus delphinus*) (Cope and Yarrow 1875 *in* Minckley 1973). Smith (1966) provided a description of the species and placed it in the subgenus *Pantosteus* (Smith and Koehn 1971). Some authors have retained the previous species name of *Pantosteus discobolus* (Minckley 1973). This issue has not been resolved, although the American Fisheries Society retains *Catostomus discobolus* (Robins et al. 1991).

The common name is a reference to the color of the head of spawning males. Body color is highly variable and ranges from silver to dark green. The ventral surface is usually white. During spawning, some individuals have a reddish lateral stripe. The species is characterized by a thin caudal peduncle (also a highly variable characteristic), rounded head, subterminal mouth with a continuous, fleshy lower lip covered with evenly-spaced papillae, and a distinct, cartilagenous (rigid), upper lip.

Bluehead sucker in Shinumo Creek were smaller (maximum = 230 mm TL) (Figure 15) than those taken from the mainstem Colorado River during other studies. Bluehead sucker taken from throughout the Grand Canyon reached maximum body lengths of 397 mm TL (n ≈ 90, Usher et al. 1979) and over 450 mm TL (n = 1,787, Maddux et al. 1987). Also, in the upper Colorado River basin, fish reach sizes greater than 430 mm TL (Andreasen and Barnes 1975; McAda and Wydoski 1983). Smith (1981) found a positive correlation between maximum body length and habitat size (stream width) for bluehead suckers (N=60). Smaller size in Shinumo Creek could be the result of shorter life spans (due to higher seasonal mortality) or simply less growth potential because of limited space and resources. It is unclear whether these patterns are "heritable adaptive variations" or "opportunistic adaptation to local resources" (Smith 1981). Northcote and Hartman (1988) showed differences in growth rates, meristic features and fecundity in rainbow trout populations isolated above waterfalls. Results of this study were still unclear whether observed differences were due to genetic differences or differences induced by environmental conditions (Northcote and Hartman (1988). Size differences between populations of bluehead sucker above and below the waterfall near the mouth in Shinumo Creek are most likely an opportunistic response to limited resources because, historically at least, bluehead sucker in Shinumo Creek could have periodically interbred with fish from below the waterfall in the Colorado River.

Age and growth information has been collected for bluehead sucker from the mainstem Colorado River in the Grand Canyon (Usher et al. 1979). The oldest fish was estimated to be in age class 8 (scale annuli count). However, scale annuli have been reported to produce false results for other western catostomids. Scoppettone (1988) provided validation for a method using opercular annuli to age Cui-ui (*Chasmistes cujus*), an endangered catostomid endemic to Pyramid Lake, Nevada. Opercular annuli counts showed fish were significantly older than was originally determined using annuli from scales. Scoppettone (1988) also aged 61 bluehead suckers from the Upper Colorado River drainage (using the opercular method) and found the oldest individual (total length = 380 mm) was in age class 18. This research suggests that bluehead sucker may be longer lived than initially reported and may discount the possibility that fish are small in Shinumo Creek because of short life spans.

I had no means of determining the age structure of the population of bluehead sucker within Shinumo Creek. The National Park Service preferrred all captured fish to be released alive. However, it seems reasonable that the population may contain some relatively old individuals despite their small size. Growth may be slow after reaching maturity between about 130 and 170 mm TL (personal observations; Otis 1993). Usher et al. (1979) reported that bluehead suckers grow to adult size in the first year but it is impossible to determine from my data if this growth pattern occurs in Shinumo Creek.

Bluehead suckers spawn in the spring and early summer over loose gravel (Maddux and Kepner 1988; Otis 1993). Maddux and Kepner (1988) observed spawning behavior in Kanab Creek in April and May at temperatures from 18 to 24°C. Additional information on gonadal development by bluehead sucker in the Weber River (Andreasen and Barnes 1975) and maturation size and fecundity from bluehead sucker in the Upper Colorado River drainage (McAda and Wydoski 1983) has been documented. I saw no ripe fish above the waterfall at the mouth during my study and only observed a few young-of-year (y-o-y) (Figure 15). The absence of y-o-y suggests that successful spawning may be intermittent in Shinumo Creek and that 1992 and 1993 may not have been very successful years for reproduction. In contrast, Havasu Creek (another tributary containing bluehead sucker) contained large numbers of y-o-y in the summer of 1993 (personal observation). In a stream where environmental conditions fluctuate as they do in Shinumo Creek, factors such as increased flow and changes in temperature may affect the success of reproductive efforts. Under extremely variable conditions, a long life span may allow survival of species despite only sporadic recruitment (Scoppettone 1988).

The absence of y-o-y bluehead suckers may occur because most y-o-y fish emigrate out of Shinumo Creek downstream to the Colorado River early in their life cycle. Such emigrations have been documented for other catostomids (Geen et al. 1966). However, if such emigration occurred for all y-o-y, fish could not re-enter

Shinumo Creek and the population upstream would disappear (Northcote and Hartman 1988).

One site on Shinumo Creek (2.7 km) had relatively high densities of bluehead sucker in July and October, 1992, and June, 1993 (Table 3). This site contained a shallow area with bedrock substrate near one bank and a deeper area near a heavily vegetated undercut bank. The site may have had high densities of fish because of large amounts of algae and other organic materials (growing on bedrock). Bluehead suckers in the Grand Canyon feed mostly over rocky substrates and stomach contents are high in detritus and benthic invertebrates (Minckley 1978; Carothers and Minckley 1981; Maddux et al. 1987). In winter and spring sample periods, high flows covered the bedrock with sand. Colder water temperatures and less algae were also observed. Under these conditions, the site contained no fish.

Little information is available concerning specific habitat requirements of bluehead sucker and no microhabitat use patterns could be determined based on my observations in Shinumo Creek. The species appears to be adapted to use a wide variety of physical conditions based on it's distribution across an extensive range of habitats. Maddux et al. (1987) found little variation in CPUE by habitat or substrate type in the Colorado River.

Upstream isolation of fish from the Colorado River

Shinumo Creek is currently divided into two separate reaches. The waterfall near the mouth prevents upstream movement of fish from the Colorado River

(Figure 7). The waterfall is formed by a large boulder that is wedged within a narrow gorge. It is unlikely that this waterfall was a permanent fish barrier before Glen Canyon Dam began regulating flows. During 1983, discharges from Glen Canyon Dam peaked at about 90,000 cfs (Figure 3) and the lower portion of Shinumo Creek was inundated with water from the Colorado River. Under these conditions, the waterfall was a drop of less than 0.5 m (personal communication, Mike Yard, GCES). Flow records from the Colorado River covering 41 years prior to the dam show one large flood where discharge reached over 200,000 cfs and several others where flow was over 120,000 cfs (Figure 3). Although, I do not know the exact level of discharge by the Colorado River needed to breach the lower waterfall in Shinumo Creek, it is reasonable to expect flows in excess of 120,00 cfs to be sufficient. However, regulated flows have reduced the incidence and magnitude of floods and, therefore, has resulted in the isolation of fish in Shinumo Creek.

Bluehead sucker in the Grand Canyon have been observed spawning during mid-March to June (personal observation; Maddux and Kepner 1988; Otis 1993). Spawning has been observed in Shinumo Creek in June, 1978, (Carothers and Minckley 1981) and one ripe female (expressed eggs) was captured at the mouth of Shinumo Creek during my study on June 23, 1993. The historic hydrograph of the Colorado River (mean daily disharge at Lee's Ferry) suggests that peak flows often occurred within the time bluehead sucker may spawn (Figure 18). In the 41 years prior to the closure of Glen Canyon Dam, the daily mean discharge was greater than

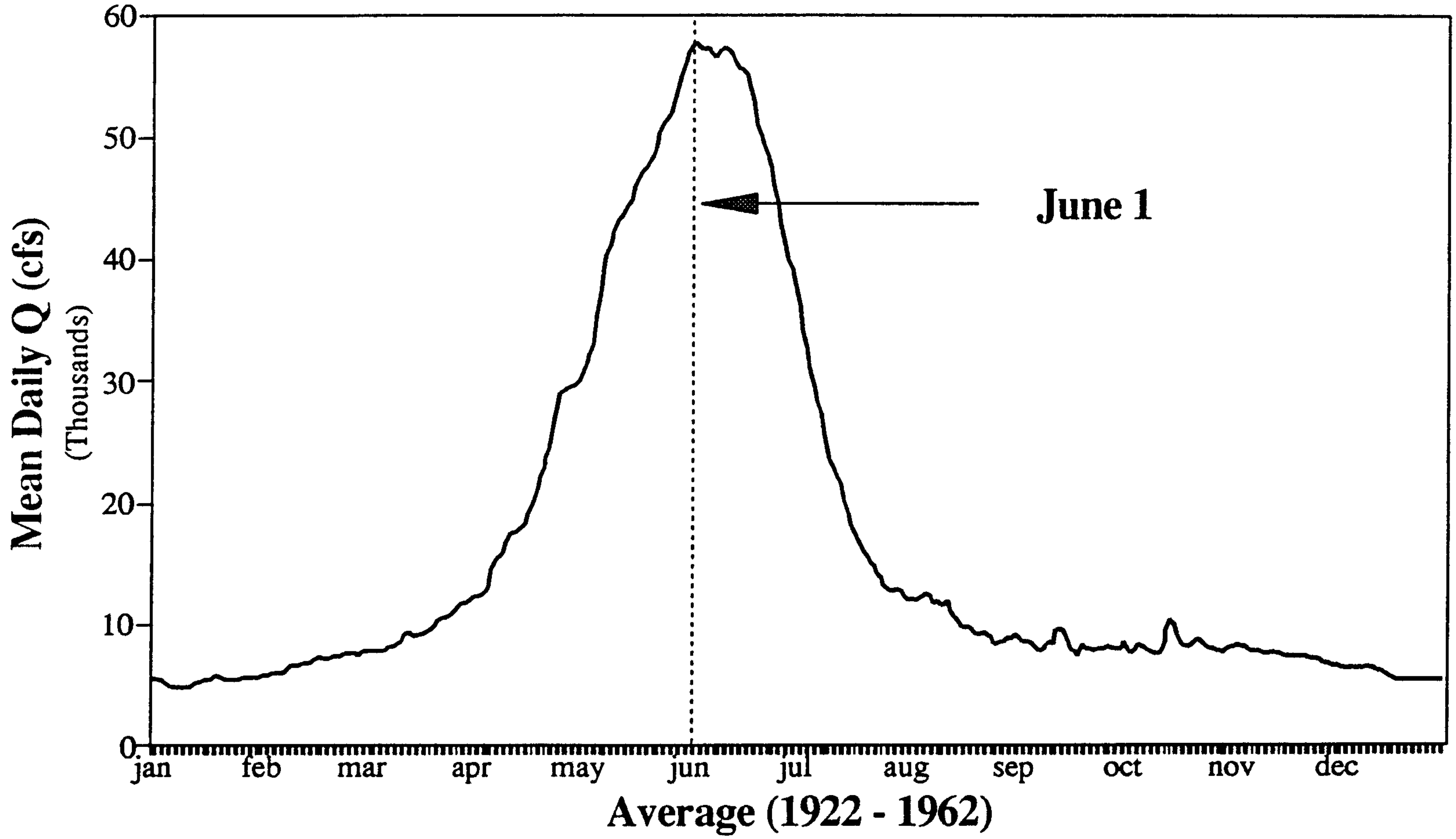

Figure 18. Mean daily flows (cubic feet per second) of the Colorado River at Lee's Ferry, averaged over 41 years (pre-dam) (data from USGS 1993).

100,000 cfs on 68 days. All but 4 of these days (2 in July and 2 in September, 1927) were between 8 May and 23 June (Table 9). If bluehead sucker were moving upstream to spawn in Shinumo Creek during peak-flow events on the Colorado River, and these flows (Figure 3) were adequate to inundate the waterfall, then bluehead suckers from below the waterfall may have been able to gain access to the upper part of Shinumo Creek on a fairly regualr basis.

However, if bluehead sucker in Shinumo Creek upstream from the waterfall have been isolated for extended periods they could represent a unique gene pool. Certainly there has been no natural movement of fish from the Colorado River into Shinumo Creek in at least 3 decades and the size structure of the population is unique among other populations.

Summary

It is impossible to determine what changes have occurred in native fish populations as a result of isolation from the Colorado River and rainbow trout introductions. There are virtually no records on fish populations in Shinumo Creek prior to these changes. However, one can speculate that the two native species that are present were the primary residents prior to these changes because of their propensity to inhabitat small streams.

Table 9. Dates where the mean daily flow (Q) of the Colorado River at Lee's Ferry was greater than 100,000 cubic feet per second (1922 to 1962) (data from USGS 1993).

Year	Month	Day	Mean Q
1922	5	28	103000
1922	5	29	110000
1922	5	30	114000
1922	5	31	116000
1922	6	1	114000
1922	6	2	113000
1922	6	3	107000
1922	6	11	104000
1922	6	12	108000
1922	6	13	108000
1922	6	14	102000
1927	7	1	119000
1927	7	2	106000
1927	9	14	103000
1927	9	15	110000
1928	5	31	104000
1928	6	1	108000
1928	6	2	113000
1928	6	3	113000
1928	6	4	109000
1928	6	5	106000
1929	5	27	101000
1929	5	28	110000
1929	5	29	111000
1929	5	30	103000
1935	6	18	103800
1938	6	7	100300
1941	5	15	105000
1941	5	16	118600
1941	5	17	117500
1941	5	18	110200
1941	5	19	102200

Year	Month	Day	Mean Q
1949	6	20	101000
1949	6	21	111400
1949	6	22	115300
1949	6	23	104200
1952	5	8	108000
1952	5	9	112000
1952	5	10	109000
1952	5	11	108000
1952	5	12	105000
1952	6	7	102000
1952	6	8	104000
1952	6	9	108000
1952	6	10	115000
1952	6	11	121000
1952	6	12	122000
1952	6	13	121000
1952	6	14	121000
1952	6	15	119000
1952	6	16	111000
1952	6	17	107000
1952	6	18	105000
1957	6	8	107000
1957	6	9	113000
1957	6	10	118000
1957	6	11	121000
1957	6	12	124000
1957	6	13	123000
1957	6	14	114000
1957	6	15	106000
1957	6	16	106000
1957	6	17	108000
1957	6	18	108000
1957	6	19	102000
1958	5	31	104000
1958	6	1	104000
1958	6	2	104000

Observations of humpback chub in the mouth of Shinumo Creek

The area of Shinumo Creek below the waterfall at the mouth provides habitat for both native and introduced species (Figure 7, Table 7). Humpback chub are commonly captured in this lower portion of Shinumo Creek by researchers and resource management agencies (Suttkus and Clemmer 1976; Maddux et al. 1987; AGFD 1993). We captured one adult (435 mm TL) and one juvenile (100 mm TL) humpback chub at the mouth of Shinumo Creek within the mixing zone (Table 7). These observations suggest that this area may be important to mainstem populations of humpback chub. There is no evidence, however, of reproductive activitiesby humpback chub in this area.

IMPLICATIONS AND FUTURE RESEARCH

Alternatives to the current operation of Glen Canyon Dam have been proposed that could potentially benefit native fish. One scenario being considered is to increase spring releases to mimic historical flood events. However, releases would probably have to be substantially greater than 100,000 cfs for the waterfall in Shinumo Creek to be breached. Discharge levels in excess of 100,000 cfs are not feasible due to the impacts on other user groups in the Grand Canyon. Even if such flows could be attained, they might allow nonnative fishes access to the upper part of Shinumo Creek.

Shinumo Creek has excellent water quality conditions and natural flow regimes. These conditions could allow Shinumo Creek to be used as an outdoor laboratory to test patterns of microhabitat use and interactions between native and nonnative species. The effects of predatory rainbow trout could also be studied. Shinumo Creek may be the only tributary in the Grand Canyon where natural conditions would allow such experiments. In addition, information on life history of bluehead suckers within Shinumo Creek remains to be thoroughly investigated and the uniqueness of the bluehead suckers above the lower waterfall in Shinumo Creek should be determined. The greatest obstacles to research in Shinumo Creek are the constraints of accessing and remaining in the area for extended periods.

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